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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

ENLARGED MEETING OF THE PERMANENT COMMISSION
(LISBON, 1949.)

QUESTION III.

Transport of miscellaneous goods.

Concentration in a certain number of selected centres (stations) of miscellaneous traffic, transport by rail between centre-stations, by road or rail between the originating point and the nearest centre-station, and also to the last centre-station near the destination.

Interest of the scheme for the conveyance of goods traffic.

Organisation of the station-centres and of the collection and delivery services.

Financial results of the scheme.

REPORT

(Austria, Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburg, Netherlands and Colonies, Norway, Portugal and Colonies, Poland, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Yugoslavia.)

by G. MOULART,

Ingénieur en chef, chef du service technique de l'Exploitation à la Société Nationale des Chemins de fer belges.

I. INTRODUCTION.

For several years, most Railways have devoted a great deal of attention to the organisation of their small goods traffic. They have in particular endeavoured to improve the service by reducing the transport time and extending their lorry services without the question of cost being a predominating factor.

Road competition was sufficient justification for the steps taken.

From the Railway point of view is

the small tonnage of miscellaneous traffic worth the sollicitude bestowed upon it?

It might be doubted when it is considered that from the point of view of tonnage and ton-miles, this traffic only accounts generally for 2 to 8 % of the total goods traffic.

There is however justification for this sollicitude.

The goods in question are of considerably higher average value than those carried in complete wagon loads, and their rapid transport has become an indispensable part of the normal economic life of modern communities.

The small amount per unit of line, the way it is closely divided up and dispersed, which is brought out by the figures given in the table (fig. 1) make it necessary to have a very flexible organisation for its transport, which must be by the most economical method.

The importance of railway parcels traffic is obviously dependent upon economic circumstances, the other methods of transport available, and also the facilities offered by the railway for complete loads.

It is found however that the railway parcels traffic is of the order of 300 to 1 000 kgr. (6 to 20 cwts.) a day per 1 000 inhabitants; that each station handles an average of 2 to 8 t. a day; that consignments and deliveries are spread over some 600 to 2 700 stations.

It can certainly be affirmed that, generally speaking, such traffic cannot economically be assured by road.

The Railway itself can only handle this traffic under proper conditions, solely in terms of the distance, when the bulk consignments to and from the large towns are also in its hands to compensate for the high cost of transport to and from the sparsely populated regions.

Now road competition is concerned solely with the former, and if measures are not taken will inevitably disorganise the equilibrium of railway rates.

It must not, in fact, be overlooked that the receipts from miscellaneous traffic amount to 12 to 26 % of the total goods receipts.

However before putting rational methods of conservation before the competent authorities, the Railways should make a thorough investigation into the best methods of transport, based on accurate costings.

The information received from the various Railways consulted shows that such an investigation, which is extremely complicated, is far from being completed.

The following report will enable each one to judge of the actual position at the present time and determine the stages to be covered before the problem is solved, within the framework of the special circumstances peculiar to each country.

The report is divided into two parts :

A. — Present organisation of the small goods traffic.

B. — Principles of the transport of miscellaneous traffic by means of special centres, and, if needs be, an extension of the terminal road services.

* * *

A. Present organisation of small goods traffic.

QUESTION I. — *What are the rights and obligations of the Railways as regards small goods traffic (nature, weight, volume, destination, loading, rates, transport time, collection and delivery)?*

All Railways must accept miscellaneous traffic of all kinds to any station open to such traffic.

There are only restrictions in the case of certain categories of goods (dangerous substances, explosives, goods which are infected or could damage other goods with which they came into contact), or parcels of excessive size (length usually limited to 6 m. [19′8¼″]) or exceeding a certain weight (500 to 5 000 kgr. [1 102 to 11 020 lbs.] according to the Railway).

The loading of the parcels into wagons and unloading is done by the Railway in the case of units which do not exceed a certain size (generally 500 kgr. [1 102 lbs.]).

In all cases the rates depend upon the weight and distance. In Finland, Greece and Turkey, they also vary according to the kind of goods; in Bulgaria and Poland there is a surcharge of 50 % on bulky goods; Italy offers express parcels services on payment of a surcharge of 25 to 50 % according to the route chosen (by stopping passenger train or express train).

Certain Railways have different rates for fast and slow goods, though several Railways with a great deal of parcels traffic (France and Belgium for example) have now combined the two.

The transport time varies from Railway to Railway; it can generally be divided into a fixed part for the time taken to collect and load the consignment (1 day) and a variable part according to the distance (1 day for each 125 to 250 km. [78 to 156 miles] according to the Railway).

Belgium and Luxemburg, owing to their limited size, have only one standard transit time, whatever the departure and arrival station.

Fast goods are delivered in about half the time of slow goods.

Lorry services for collecting and delivering parcels have been organised by most European Railways in all towns and districts of any size.

In Bulgaria and Poland, as well as on the colonial Railways, such services are very rare if not non-existant.

QUESTION II. — *What is the position of road hauliers for all the points covered in Question I?*

Except in Norway, Poland and Sweden, road hauliers have complete freedom, from the point of view of selecting what goods they will carry, destination, and rates : they are able to charge different clients different rates.

In France and its colonies, maxima fixed by the Government must be respected in road transport tariffs.

In Norway and Sweden, co-ordination of transport has been achieved since the 1st January 1948, and road hauliers are governed by more or less the same regulations as the Railways.

In Poland, co-ordination is being studied; in the meantime most road transport is covered by a State organisation, the remainder by co-operative transport and a few private hauliers under State control.

QUESTION III. — *What is the total extent of your system, the total population served, the total number of stations, the number of stations open for parcels traffic, the number of stations with collection and delivery services and the population benefiting thereby?*

The information received concerning the principal Railways is summed up in the following table (fig. 1).

It will be seen from the above that :

a) 75 to 100 % of the stations are open for parcels traffic;

b) the number of stations where there is a lorry collection and delivery service is generally very small;

c) the population profiting by organised delivery and collection services is a relatively small proportion (Switzerland 80 %; Belgium 77 %; France 60 %;

COUNTRY	Extent of system in km.	Total population (in millions)	Number of stations			Population served by stations with collection and delivery services	Average daily tonnage	
			Total	Open for parcels traffic	With collection and deliv. services		per station	per 1 000 inhabitan
French West Africa. (Dakar-Niger)	1 679	2	100	100	—	—	1.05	0.053
Algeria	4 338	4	465	381	23	—	1.12	0.131
Austria	5 910	6.8	972	972	173	—	2.30	0.330
Belgium	4 950	8	1 618	1 211	370	6.2	2.20	0.330
Bulgaria	3 471	6.2	420	383	—	—	1.54	0.095
Denmark	2 595	4	539	437	269	—	7.60	0.800
Spain	12 798	20	1 876	1 432	305	—	—	—
Finland	4 721	4	1 408	671	42	1	6.20	1.030
France	41 300	40	5 880	5 530	2 048	24	6.80	0.350
Greece	830	4.5	156	95	34	2.5	0.69	0.024
Italy	16 037	45	—	2 696	406	15	2.20	0.130
Luxemburg	392	0.28	92	92	10	0.13	—	—
Madagascar	859	1.25	85	85	—	—	10.60	0.720
Norway	4 380	2.5	692	650	55	—	3.90	1.010
Sweden	12 429	6	1 477	1 470	549	3	4.80	1.180
Switzerland	2 899	4.4	827	676	658	3.5	5.90	0.900
Tunisia	455	0.5	26	23	—	—	—	—

Fig. 1.

Greece 55 %; other countries less than 50 %);

d) the average daily tonnage per station varies between 2 and 8 t. a day; it is appreciably less if the traffic at the large stations is left out of consideration. This average however gives some idea of the general dispersion of the parcels traffic;

e) the average daily weight of the parcels traffic per 1 000 inhabitants generally lies between 300 and 1 000 kgr. (660 and 2 200 lbs.).

QUESTION IV. — *What is the average daily extent of the small goods traffic in tonnes, tonnes-km., number of consignments, number of wagons used, receipts?*

Make a comparison between these figures and those for complete loads.

The replies received have been summed up in the tables (figs. 2 and 3) and bring some interesting facts to light :

a) the relative amount of the parcels traffic in tonnes and tonnes-km. is very low compared with the total goods traffic;

b) the percentage of parcels traffic compared with the total goods traffic is appreciably the same as the tonnes-km., which means that the average journey for small consignments is equal to that for complete loads;

c) the low average weight of parcels, apart from handling charges, involves very high costs for booking in, classification and delivery;

d) the miscellaneous traffic receipts form a considerable part of the total receipts (from 12 to 26 % — the rate of 55 % reported in Finland is the result

COUNTRY	Miscellaneous traffic			Complete loads		
	Tonnes/ day	No. of consignments	Average weight per consignment kgr.	Tonnes/ day	No. of consignments	Average weight per load kgr.
French West Africa	105	355	295	1 422	68	20 900
Austria	2 240	2 880	781	7 850	4 900	1 600
Belgium	2 620	63 160	41	209 180	6 736	31 000
Bulgaria	590	2 012	293	15 000	1 100	13 600
France	13 984	182 507	77	376 183	21 020	17 900
Sweden	7 075	202 825	35	104 690	5 250	19 900
Spain : total	No distinction between miscellaneous traffic and complete loads.			71 348	59 433	1 200

Fig. 2.

Fig. 3. — COMPARISON OF AVERAGE DAILY TRAFFI

COUNTRY	Tonnes			Tonnes-Km.		
	MG	CW	MG / MG+CW %	MG	CW	MG
French West Africa .	105	1 422	6.9	37 615	543 056	
Algeria	523	14 182	3.6	148 406	2 833 412	
Belgium	2 620	209 180	1.24	244 840	20 345 754	
Spain	—	71 348	—	—	18 508 577	
Finland	4 141	36 971	10.0	1 035 250	9 553 664	
France	13 984	376 183	3.6	4 700 000	98 195 000	
Greece	108	1 026	7.25	12 850	167 500	
Italy	5 930	85 428	6.5	2 253 002	32 445 804	
Sweden	7 075	104 690	6.3	1 173 425	18 460 020	

of the large amount of miscellaneous traffic, which appears to be due to the absence of road competition);

e) a comparison between the receipts per tonne-kilometre for parcels traffic and complete loads reveals some singular anomalies :

The ratio between the unit receipts for the two categories of traffic lies between 2 and 5 on most Railways.

In Belgium and Finland however it is more than 11.

Though the unit receipts vary from one Railway to another according to the nature, importance and distance for consignments in each category, the special case of Belgium and Finland would appear to be the result of disproportionate rates for small consignments and complete loads.

The lesson to be learnt from these figures, and the absence of details in most countries, is that the accounting system of the Railways does not make it possible at the present time to establish the cost of the different kinds of transport.

Although such a calculation of the cost is particularly difficult in the case of Railway undertakings owing to the dispersion of the installations, the variety of the services, and the fact that they come under different categories of transport, the Railways should make every effort to do so, just like any other industrial concern.

The necessity for so doing is rendered

LANEOUS GOODS (MG) AND COMPLETE WAGON LOADS (CW)

Receipts			Receipts per Tonne-Km.		
MG	CW	MG / MG+CW %	MG	CW	MG / CW
7 000 Fr. fr.	1 211 000 Fr. fr.	18	7.10 Fr. fr.	2.27 Fr. fr.	3.12
2 088 Fr. fr.	6 400 040 Fr. fr.	11.75	5.74 Fr. fr.	2.26 Fr. fr.	2.54
0 530 Belg. fr.	15 877 460 Belg. fr.	12	8.82 B. fr.	0.78 Belg. fr.	11.30
—	3 731 966 Pes.	—	—	0.202 Pes.	—
2 040 Mk.	19 560 000 Mk.	55.3	23.5 Mk.	2.05 Mk.	11.46
5 000 Fr. fr.	195 673 000 Fr. fr.	19.9	10.37 Fr. fr.	1.99 Fr. fr.	5.21
76 545 Dr.	39 244 400 Dr.	13.4	473 Dr.	234.5 Dr.	2.02
2 591 L.	113 959 870 L.	16.6	10.06 L.	3.51 L.	2.87
0 385 Cr.	825 720 Cr.	26.0	0.25 Cr.	0.045 Cr.	5.55

even more imperative by the fact that the cost should logically be the basis upon which the rates are calculated, as well as the co-ordination of transport for which all railway undertakings are clamouring.

QUESTION V. — *How are small consignments booked in and out, at the station or when they are collected and delivered; please describe the formalities to be observed and documents to be completed, together with the office installations needed?*

All the Railways make use of waybills, which are either prepared in several copies, or consist of various parts.

The various copies or parts are used as receipt for the consignor, official waybill, notice of arrival, and receipt for the consignee.

The waybill must show all the details needed for identifying the parcel, the route to be followed, the charge made (nature, weight, number and marks on parcels, names and addresses of consignor and consignee).

Goods may be sent carriage paid or carriage forward; if they are collected from the consignor the waybill is prepared either by the consignor or the lorry-driver (Austria, Sweden, Switzerland), or at the station, in which case the driver gives the consignor a provisional receipt. The charges are paid later on.

On arrival, the consignment is given to the consignee against the waybill,

which has to be signed, this document being first of all withdraw at the goods office, provision being made if needs be for the payment of the charges.

If the consignment is delivered home, the driver carries out all these formalities on behalf of the Railway.

Except in Finland, no special documents are prepared when part of the transport takes place by lorry.

The station depots must be accessible for both lorries and wagons.

QUESTION VI. — *Describe the general organisation of your miscellaneous traffic (slow goods, express goods, postal packages).*

All the Railways use pick-up and distributing wagons and through wagons for their miscellaneous traffic. On European Railways with a great deal of this traffic separate wagons are run to pick-up and deliver goods (Austria, Belgium, France, Italy).

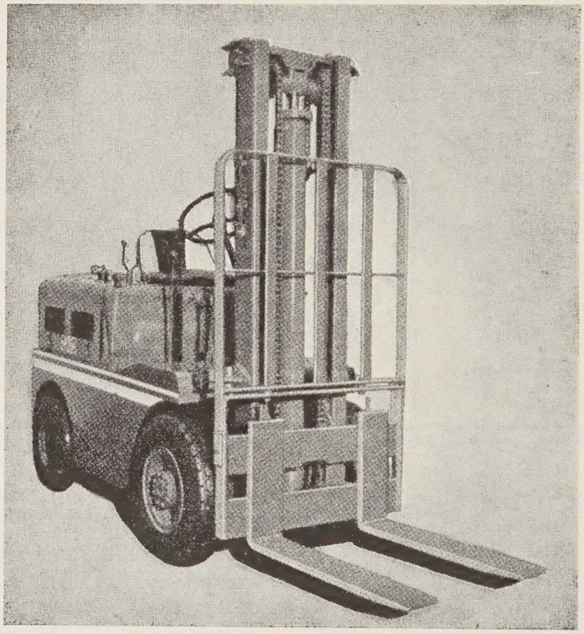


Fig. 4.

The miscellaneous traffic is dealt with on a raised platform under cover, the dimensions being proportional to the average daily tonnage (1 m^2 for every 50 to 80 kgr. [110 to 170 lbs.] of goods according to their kind).

According to the amount of parcels to be handled, two-wheeled trucks, hand-trucks, or electric trolleys (Fenwich type), self-lifting electric trolleys (fig. 4) of motor trolleys with trailers are used.

Only in Austria, Belgium and France are such wagons systematically handled in specially equipped central depots (centre-stations).

The organisation can be summed up as follows :

— in principle each collecting wagon

is directed towards the centre station or transhipment station of its area. Goods are transhipped and loaded into through wagons to the centre-station of the destination area. This station loads up the distributing wagons serving the different stations in its area (in theory therefore two transhipments);

— to reduce intermediate handling, every station is authorised to complete through wagons to another station (sometimes for several adjoining stations) or to the destination centre-station, so long as there is a minimum tonnage (3 to 5 tons according to the Railway);

— for the same reason, the first centre-station completes through wagons for certain destination stations, respecting this same minimum tonnage.

These measures reduce the average number of transhipments — which are costly and delaying operations — to 1 (in Belgium) and 1.7 (in Poland).

Wagons generally travel between the centre-stations by fast goods train; special trains for certain important services, mixed parcels trains and complete wagon loads in other cases.

The pick-up and distributing wagons travel by stopping goods trains, and sometimes, on secondary lines, by stopping passenger trains.

In Belgium and France there is no longer any distinction between slow and express goods. Only express parcels and postal packages receive a special treatment, being sent by passenger train.

There is a similar organisation in Italy and Switzerland, but goods can still be re-handled in the junctions and during the journey.

In addition on certain important routes in Italy, there is an express service (surcharge of 25 or 50 % on the usual rates) by speeded up goods trains (or by passenger trains).

The goods are loaded into special corridor wagons, which are lighted and heated. Gangs travel on the train and deal with the parcels so as to group them according to the destination stations or lines, thereby avoiding the need for transhipment at the stations.

Although somewhat expensive, this organisation seems to be worth considering in cases where there is sufficient traffic to keep the staff travelling on the trains fully employed.

Systematic routing by the use of centre-stations gives three important advantages : rapidity of transport, good utilisation of the wagons, reduction of the amount of transhipment involved (in Belgium and France the number of wagons used has decreased by 30 %, though the volume of traffic is still the same).

Other Railways make use of a mixed organisation using pick-up and distributing wagons over routes of various lengths, which are reallocated during the run or at the junction or transhipment stations and through wagons. All the wagons travel by ordinary goods trains.

The Railways which still have an express goods (G.V.) tariff (Denmark, Poland, Sweden and Switzerland) send such consignments by passenger trains (wagons or vans).

Special wagons (often open wagons) are used for corrosive or dangerous goods.

No Railway makes use of wagons divided into compartments, except in Belgium for newspapers, and Greece for international traffic.

Each Railway considers that its own organisation is the best suited for the system and traffic. In fact it is true that in every country the average wagon load varies between 3 and 3.5 t. Italy and Poland alone have an average of 5 t.; there is nothing special about their

organisation, but it appears that the better user of the wagons is due to an increase in the transit time for slow goods traffic.

QUESTION VII. — *On Railways with transhipment platforms :*

a) *Are these platforms linked up daily in pairs by through parcels trains?*

Only Austria, Belgium, Spain, France, Norway, Poland and Switzerland run special parcels trains.

Before the war, connecting trains were run in Belgium between the various transhipment platforms. By means of these trains nearly 75 % of the miscellaneous traffic was delivered before midday the day after they were collected. However it cost a great deal to organise these trains; consequently some of them have been suppressed and only the through services between the most important depots have been retained. The other countries mentioned have done the same.

These trains run at various speeds, according to the Railway, from 40 to 80 km. (24 to 50 miles)/h. and usually consist of 30 to 40 wagons (400 to 450 t.).

b) *Are the transhipment depots the termini for the stopping collecting and distributing trains?*

Spain, Finland, France and Italy replied in the affirmative.

In Belgium some of the stopping trains are made up at the platform stations, others by the neighbouring shunting station.

The average speed of these trains is low : 10 km. (6 miles)/h. in Italy, and 20 to 40 km. (12 to 24 miles)/h. in most of the other countries.

They are also smaller than the through trains : 20 to 30 wagons.

QUESTION VIII. — *In certain cases are the distributing or collecting wagons and the through wagons conveyed over all or part of the run by ordinary goods trains with the complete loads?*

On Railways, who have no transhipment platforms, the slow parcels traffic is all worked by ordinary goods trains.

On the other Railways, long distance transport in the case of important services is dealt with by the parcels trains (see Question VII) ; other goods go with complete wagon loads.

As for the stopping services (collecting and distributing sections), these are always worked by means of the ordinary goods trains, except in France and Italy where stopping parcels trains are run over all lines of any importance.

QUESTION IX. — *How do you decide the site and number of your transhipment platforms : is it according to the layout of the system, the tonnage to be handled, the population of the district, etc.? Are such platforms only accessible by rail, or is it best for them to be also accessible by road?*

The 14 Railways interested in this question (Algeria, Austria, Belgium, Spain, Finland, France, Italy, Norway, Denmark, Poland, Sweden, Switzerland, Tunisia and Turkey) are unanimous in agreeing that the siting of the transhipment platforms is determined by the layout of the system. This means that they must be set up at important centres of communication.

Ten Railways consider that the tonnage to be handled must also be taken into account.

According to the French Railways, the local traffic must also be taken into account, if this must be of considerable importance. It can then be decided what equipment will be needed to handle the tonnage of goods to be transhipped.

As for the question of linking up such platforms with the railway alone, or with the railway and the roads, the situation is as follows : half the Railways have platforms only accessible by rail, while on the other half they are also accessible by road.

There is a definite tendency in favour of the latter plan in order to make it possible to organise lorry services for the collection and delivery of goods.

In Belgium, where prior to 1940 certain transhipment platforms were only accessible by rail, advantage is being taken of war damage to rebuild them with road access as well.

Italy has laid down fairly strict standards for the siting of the transhipment platforms. In principle a platform is constructed when the average number of wagons to be dealt with daily is at least 10.

There are three categories of transhipment platforms :

— small installations, for up to 15 wagons, covering a distance of 100 km. (62 miles);
— average sized installation, for up to 30 wagons, covering a distance of 200 km. (124 miles);
— large installations, for more than 30 wagons, covering up to 300 km. (186 miles).

QUESTION X. — *What standards are laid down for your transhipment depots, according to the tonnage and kind of traffic : dimensions, arrangement of the sidings, handling equipment?*

Up till recently, transhipment depots have always been covered sheds with raised platforms, the number, width and length of which depended on the tonnage to be handled.

The necessary platform area, apart from the runways, can be calculated as a square metre (10.76 sq. ft.) for every 50 to 80 kgr. (110 to 176 lbs.) according to the bulk of the goods dealt with.

The following standards are used in France, for the preliminary calculations:

— arrivals : 50 kgr. (110 lbs.) per m^2;
— transhipment : 80 kgr. (176 lbs.) per m^2;
— consignments : 70 kgr. (154 lbs.) per m^2.

It is usually considered that the platforms should be 8 m. (26′3″) wide and their length should not exceed 250 m. (820′) to avoid unduly long hauls.

When the length exceeds 100 m. (328′), it is advisable to provide intermediate passages from platform to platform, either between the wagons, or through them by using light moveable gangways.

At Brussels transhipment station (800 t. per day) the platforms are interconnected by lifting bridges worked electrically, at the ends of the platforms and halfway along them (fig. 5). The main platforms are 11 to 16 m. (36′1″ to 52′6″) wide and 250 m. long, while the intermediate platforms are only 6 m. (19′8″) wide.

The maximum length of platform allowed in Switzerland is 140 m. (459′4″), with a certain number of parallel transhipment sidings alongside intermediate platforms with a minimum width of 2 m. (6′6¾″), and on each side of this layout, an arrival platform on one side, and a consigning platform for local traffic on the other (fig. 6).

In France after a reexamination of the problem, it was decided to retain the classical type of depot with wide transhipment platforms and a very big platform at the side for local traffic (fig. 7), when the tonnage to be transhipped does not exceed 1 000 t. a day.

In the case of the larger depots, the English solution of a depot without platforms has been adopted (fig. 8). The wagons to be transhipped are put into

position on the unloading sidings, the parcels are unloaded onto conveyor belts which take them to the trucks (inside trucks with a platform of 8 m² [86 sq. ft.] able to carry 1 tonne), on which they are grouped according to destination. As soon as the trucks are full, they are taken by tractor to the loading yard and the goods are transferred into the wagons corresponding to their destination. The trucks loaded with goods for the locality are collected in front of the arrival sidings, while the goods to be sent off, received at the collecting siding, are also taken by trucks to the loading yard. The plat-

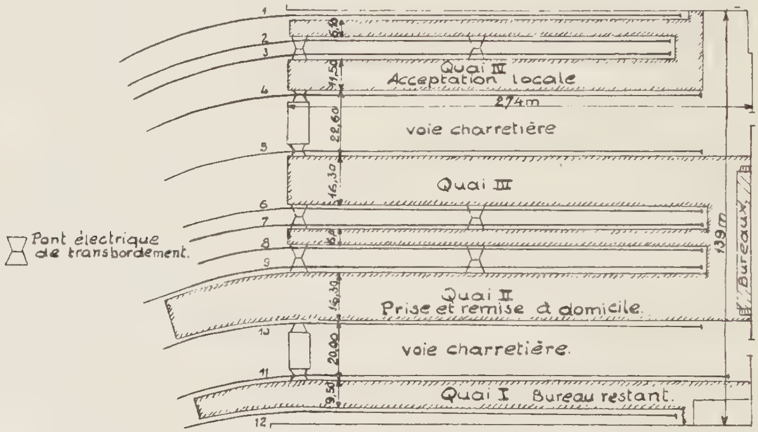
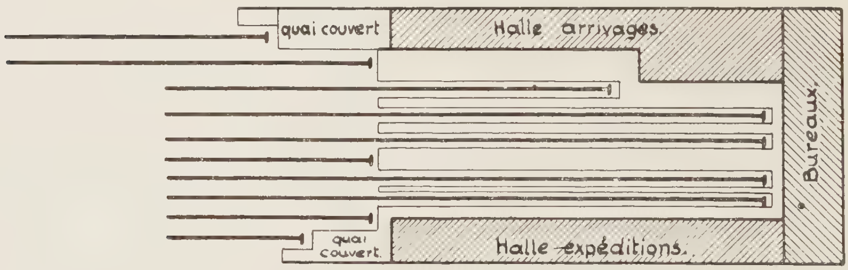


Fig. 5. — Brussels Tour et Taxis. Goods transhipment depot.

Explanation of French terms :

Quai = Platform. — Acceptation locale = Local receiving office. — Voie charretière = Road for hauliers. — Prise et remise à domicile = Door to door collection and delivery. — Bureau restant = Goods depot. — Pont électrique de transbordement = Electric transhipment bridge.



Maximum length of platforms : 140 m. (460′).
Width of intermediate platforms : 2 m. (6′6¾″).

Fig. 6. — Diagrammatic plan of a transhipment depot with local goods services (Switzerland).

Explanation of French terms :

Quai couvert = Covered platform. — Halle arrivages = Depot for arriving goods. — Bureaux = Offices. — Halle expéditions = Consigning depot.

forms of the trucks are naturally on the same level as the floor of the wagons to facilitate handling.

This organisation, which limits considerably the size of the installations required, reduces and speeds up the turnround of stock used for the transfer of goods.

QUESTION XI. — *How is the work organised in the transhipment depots :—*

a) *Is the work all done by day or by night as well?*

Only four Railways (Algeria, Italy, Norway, Tunisia) work exclusively by day.

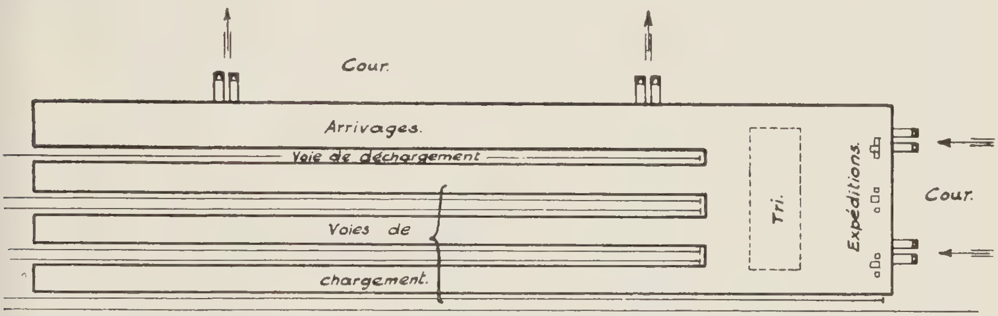


Fig. 7. — Classical type of depot with platforms.

Explanation of French terms :

Cour = Yard. — Arrivages = Arrivals. — Voie de déchargement = Unloading platform. — Tri = Sorting out. — Expéditions = Consignments. — Voies de chargement = Loading platforms.

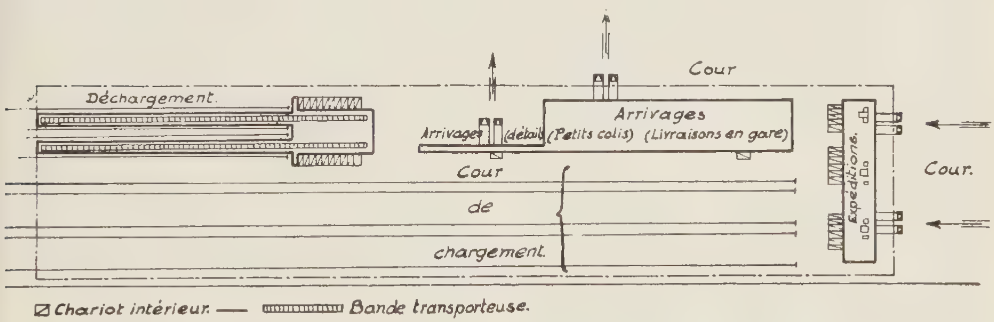


Fig. 8. — Depot without platforms.

Explanation of French terms :

Cour = Yard. — Déchargement = Unloading. — Arrivages (détail) = Arrivals (detail). — Arrivages (petits colis) (livraisons en gare) = Arrivals (small parcels) (station delivery). — Cour de chargement = Loading yard. — Expéditions = Consignments. — Chariot intérieur = Inside truck. — Bande transporteuse = Conveyor belt.

In Denmark saw-toothed platforms are preferred at the large transhipment centres. Although this arrangement has the advantage of enabling wagons to be shunted in any desired order, it makes the work a great deal more laborious.

The other Railways work both day and night in all or some of their depots. In most cases, night work reduces the journey time by 24 hours.

b) *Are local consignments kept separate from those from other depots?*

On every Railway, all the goods are dealt with together, apart from a few exceptions in Belgium, France and Italy.

Such a division would appear to be necessary however in the case of depots working at night.

c) *Are consignments collected during the day handled in the local depot on the same day or the following day.*

In Algeria, Belgium, Spain (express goods), Finland, France, Switzerland and Turkey on the same day.

In Spain (slow goods), Italy, Norway, Sweden and Tunisia, on the following day.

The first solution is to be recommended as it reduces the transit time.

d) *Are consignments received incorporated in the distributing trains on the same day or on the following day?*

On most Railways, goods arriving are not dealt with until the following day.

The only exceptions are on those Railways and in those depots where work is continued during the night.

This is a cause of delay which, it appears, might be avoided in many cases.

e) *How are the parcels checked during handling operations, with or without their waybills?*

Nine Railways out of 16 carry out transhipment without the waybills. Amongst these Railways are those with the heaviest parcels traffic.

It can therefore be considered that the expensive operation of checking consignments against their waybills is unnecessary, seeing that each parcel bears all the information necessary for its routing, in particular a ticket showing the number of the destination district (lots).

The waybills are sent off at the same time so that they will arrive at the destination stations in good time.

f) *Average daily output, in tons handled, of the depot staff.*

This is generally between 4 and 6 tons. It varies in inverse proportion to the importance of the depot and is lower when the goods include a large number of bulky packages.

However in France, where an output of 6 tons has already been achieved, it is hoped to increase this figure in the large mechanised depots without platforms.

QUESTION XII. — *What proportion of containers are used for parcels traffic? On what are the rates for consignments (net or gross weight) and returned empties based? To whom do the containers belong? Advantages.*

Containers are very little used on any of the Railways, if at all.

Even those Railways who have some containers only make use of them to group consignments of parcels. This is due to the fact that the object of the organisation in force is to reduce intermediate handling to the very minimum, and this reduces the value of using containers for internal traffic.

When containers are used by consignors, the rates are usually based on the net weight when the containers belong to the Railway or have been approved by it, and when empty no charge is made if this is after or before a journey loaded.

In Italy however the rates are based on the gross weight, while in Spain and France returned empties are charged in all cases.

Switzerland reports the use of depot trucks in which all the parcels for the same destination are grouped as far as the terminus station.

All the Railways are unanimous in recognising the value of containers from the point of view of ease of handling, loss, and damage.

QUESTION XIII. — *Outside the collecting and delivering areas, are express parcels and postal packages accepted under the same conditions as ordinary goods or do they profit by any special arrangements for the journey?*

The rule is that they travel by fast goods train on the main lines, and by passenger train on the secondary lines.

QUESTION XIV. — *What is your opinion about haulage agents making grouped consignments?*

a) *Is their business an advantage for the Railway?*

The 13 Railways concerned (Algeria, Austria, Belgium, Denmark, Spain, France, Greece, Italy, Luxemburg, Norway, Sweden, Switzerland and Turkey) replied in the affirmative.

It is justified by the increase in the number of through wagons, which reduces the formalities for accepting and handing over goods, as well as the handling done by the Railway.

b) *What rates are they allowed?*

Wagons dispatched by grouping agents are generally charged under the rates for complete wagon loads. In Algeria, Austria, Spain, France and Switzerland the agents are allowed still more favourable rates.

c) *If the development of road traffic encourages it, is there not a risk of agents profiting by their favourable position to take traffic away from the Railway? If the occasion arises, what steps will you take to prevent this?*

This problem does not arise in Norway, Poland and Sweden where road transport is regulated.

In Algeria, Austria, Spain, France and Switzerland agents have to sign a contract in order to profit by the reduced rates and various other facilities (buildings in the railway precincts in particular).

The other Railways do not think they can defend themselves in any other way than by rating measures, so long as the public authorities have not coordinated the methods of transport.

It may be mentioned that in Switzerland, agents cannot deal with transport over distances greater than 15 km.

d) *What tonnage is sent to the Railway by grouping agents.*

The tonnage of parcels traffic sent to the Railways by grouping agents compared with the whole of this traffic is :

— in Algeria	5 %
— in Denmark	6 %
— in Belgium	11.5 %
— in Austria	18 %
— in France	
— in Sweden	

QUESTION XV. — *What part do the secondary railways play in forwarding parcels?*

Do they act as a terminal service (collecting and delivering) or do they carry out long distance transports?

In all countries where there are secondary railways, the latter have through rates or their rates are based on those of the main line railway.

In Belgium, Finland and Poland they do not carry out any through transport, but the contrary is the case in Austria, Bulgaria, France, Italy, Luxemburg, Sweden and Switzerland.

In Belgium and France the inter-railway traffic is only 2 % and 1.5 % respectively of the main line railway traffic; in Switzerland it is as much as 25 to 30 %.

QUESTION XVI. — *How are your door to door services organised?*

a) *Types and characteristics of lorries used.*

All types of lorries are used from the mechanical horse for short distances to 5 ton petrol lorries, together with 10 to 20 cwt. vans and 3 or 4 ton lorries.

3 to 5 ton lorries are however the most numerous.

The bodies are generally of large capacity (10 to 16 m^3 [353 to 565 cu. ft.]), as bulky goods often have to be carried. In Belgium 20 m^3 (706 cu. ft.) lorries are used for containers; these lorries are equipped with a movable gangway and a winch to facilitate the loading and unloading of the containers (figs. 9 and 10).

Low loaders are preferred (floor 1.05 m. [3′5³/₈″] above ground level) to facilitate loading and unloading, with raised driving compartments for the staff (fig. 11).

In France and Belgium electric lorries running on accumulators are also used (load 3 tons, volume 14 m^3 = 494 cu. ft.) (fig. 12) for services in the large towns within 10 km. (6 miles) at the most from the station; the daily mileage cannot exceed 50 km. (31 miles), because of the capacity of the accumulators.

In Belgium a lift gate apparatus is about to be tried out which can be fitted on the rear end of all lorries (figs. 13 and 14) making it easy to load and unload very rapidly parcels weighing as much as 1 000 kgr. (appr. 2 200 lbs.).

Fig. 9.

b) *Sphere of action.*

The lorry services are usually only run in the towns, and their sphere of action rarely exceeds 12 km. (7 miles).

c) *Places served.*

The Railways are not generally under any obligation to organise cartage services in the towns.

However in France and Algeria the Railways have to organise such services in the case of all places with more than 5 000 inhabitants within 5 km. (3 miles) of a station.

Fig. 10.

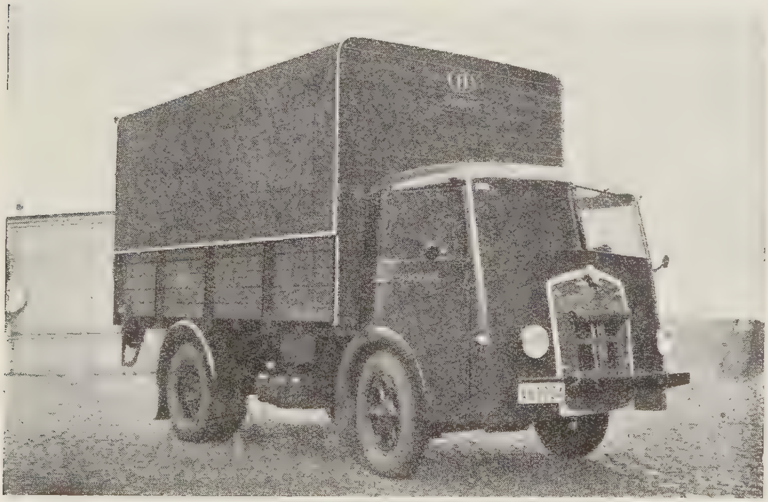


Fig. 11.

d) *Do you set up any depots outside the railway installations; if so under what conditions?*

Such depots have only been set up in Belgium, Denmark, Spain, France and Switzerland.

In Denmark and Spain there are only town depots.

In Switzerland, they are more numerous and usually set up in post offices on the way followed by the lorries.

In France, they are usually set up with agents.

Fig. 12.

Fig. 13.

In Belgium, they are set up in rural districts some way away from the railway, where the small number of people and scattered nature of the houses makes the organisation of door to door services unpracticable. An agreement is made with a haulier running a standard lorry service.

e) *How are parcels delivered, and how soon after arrival at the station?*

In theory, the goods are handed over to the haulier the day they arrive.

Certain Railways (Italy and Norway in particular) only hand them over on the following day.

Two services a day are usually organised in the large centres and one for the inter-town services and secondary centres.

delivering all goods; this simplifies shunting on arrival and reduces the amount of goods that have to be stored.

Various Railways doubt if it is possible to do so however, as several important clients have their own means of transport.

g) *What happens with express parcels and postal packages?*

These are delivered within 3 to

Fig. 14.

6 hours wherever lorry services have been organised.

f) *Do you limit the door to door services to parcels for which it is asked?*

Would it not be better to deliver all parcels?

In Belgium, Denmark, Finland, France, Italy (express goods), Norway and Switzerland, all goods are delivered on arrival, unless the consignee or consignor has made any stipulations to the contrary.

In France, the cost of delivery is included in the rates.

All the Railways with lorry services have stated that they are in favour of

h) *When and within what time limits are goods collected from the consignor?*

Goods are collected the same day as the request is made, or the next day at the latest.

i) *What is the average daily mileage of a lorry and its output?*

The average daily mileage lies between 25 and 50 km. (15 and 31 miles) according to the Railway and service given; the smaller mileages are found

in the case of smaller places, or journeys in districts very near the station.

The output of a lorry varies from 3 to 5 tons per 8 hours working day.

In France, it is taken as twice the useful load, except in Paris where it is 5 tons (average mileage 45 km. = 28 miles).

Switzerland reports an output of 8 to 10 tons, which is far above the average.

j) *What staff travel on the lorries?*

There is generally a driver and another man to make the deliveries, sometimes two men. On the vans, the driver often makes the deliveries himself.

k) *How are the rates for door to door services calculated?*

In Spain, France, Greece, Italy, Luxemburg, Norway, Poland, Sweden and Switzerland, the rates are a function of the weight and the distance. As it is difficult to determine the latter in the case of large towns, these are divided up into districts.

Only in Belgium and Finland are the rates independent of the distance.

This appears to be a mistake, enabling private hauliers to compete against them on the short runs, which upsets the equilibrium of the rates.

l) *What is the proportion of door to door services compared with the total traffic?*

In most countries 30 to 40 % of the total traffic is delivered. It is below this figure in Spain, Finland and Italy.

The proportion of traffic collected is much lower : 5 to 15 % on the average. This appears to be due to the fact that many large consignors bring their goods to the station in their own lorries or send them by private hauliers. The delivery services, which are more scattered, are left to the railway.

The above percentages are appreciably exceeded in the large towns : in Brussels for example the figures are 65 % for delivery and 34 % for collection.

m) *Do you consider that the door to door rates should cover the cost of such services, or is it in the interest of the Railway to run them at a loss in order to attract traffic?*

Opinions are divided.

Algeria, Austria, France, Norway, Poland and Sweden consider that the rates should cover the cost.

Belgium, Spain, Finland, Greece, Italy, Luxemburg and Switzerland are of the opinion on the other hand that the Railway should try to keep its customers and attract new ones by offering attractive door to door services, even if these are run at a loss. Such a sacrifice is justified by road competition.

n) *Do you prefer to operate the cartage services yourself or on contract, and for what reasons?*

The majority of Railways prefer to have such services operated by contract, but they agree that in the large centres it may be advantageous to run them themselves.

The organisation by the Railway of a multitude of small scattered lorry services would be very costly, and in such cases it is better to have recourse to local firms who can combine such services with their other business.

This argument does not apply in the case of the large centres where it would moreover be difficult to find a private firm with the necessary number of vehicles.

In actual fact, two groups of factors come into play which are only contradictory in appearance : on the one hand there is the economic advantage of using a private firm whose general costs

and social obligations are considerably less than those of the Railway, which usually has not to respect the strict working hours with the same rigour as the latter (they are frequently family concerns);

and on the other hand, the interest the Railway has in keeping a very close hand on the haulage services in order to keep a check on the quality of the service and prevent traffic being lost to its competitors.

In Belgium a system which reconciles the two points of view is being tried : lorries with their drivers are hired from private firms (hourly rate lower than it costs to run its own lorries), a man to make the deliveries is sent out with each lorry and they are used as required, just as if they were their own lorries.

This system has not been working long enough for any conclusions to be drawn, but they would appear to be favourable. This system which standardises the haulage services in a district in a practical way and maintains contact between the Railway and its clients, has the advantage that private firms have not raised any objections to it since they are not left out of the picture.

o) *If you run your own cartage services :*

Are the lorries owned by the Railway?

The lorries are owned by the Railway, except in France and Sweden where a subsidiary company has been set up, except in the case of the services to small places.

— *When and how do you decide the number of lorries to be run daily?*

Varying : according to the previous days traffic or that for the corresponding day of the previous week.

— *How is the itinerary of each lorry determined?*

In the large towns, each lorry generally serves a given district, and its itinerary is determined according to the addresses of the consignees.

In the case of long runs, definite routes are always followed, choosing the shortest and best roads.

— *Are the lorries loaded in the presence of the delivery man?*

Except in Finland, Luxemburg and Switzerland, the delivery man assists with the loading, as apart from checking that the parcels are there, he is the best able to group them according to the most suitable itinerary.

This is not done in France except in the case of trailers.

— *How is the output of the lorries checked?*

A list is drawn up for each lorry run showing the weight of the parcels carried. The mileage indicator shows the distance covered. These indications, together with the details of the petrol and oil consumption make it possible to assess the output of the lorries and the unit cost (lorry-km. or tonne-km.) of this transport.

p) *In the case of services worked by private firms :*

— *How is the firm chosen : by simple agreement or by contract?*

Both methods are found. In Algeria, Austria, Belgium and Spain it is by contract; whereas in Denmark, France, Luxemburg, Norway, Sweden and Switzerland, simple agreements are made, taking into account the prices proposed, as well as the guarantees offered by the firm from every point of view (honourableness, serviceability, etc.).

In Italy all the haulage services are

in the hands of a private company in which the Railway has a great interest.

A long term agreement has undoubted advantages : the certainty of keeping his job as long as he is satisfactory leads the holder to serve the Railway loyally and prevent it losing traffic.

— *How long do the contracts last?*

In the case of contracts, 6 months to 10 years according to the Railway; it can be determined by either party on giving 3 or 6 months notice.

In the case of agreements, the period is indefinite, and each side can give 3 months notice to terminate it.

— *How is payment made : by the tonne, tonne-km., hour, lorry-km., etc.?*

As a general rule payment is made, as the tariffs, according to the weight and mileage. The latter element comes into the picture by dividing up the district into zones. The unit rates may vary from one place to another according to the density of population and geographical conditions.

Only in Belgium is payment based on the number of consignments and scales of weight.

— *Do you prescribe the use of certain types of lorries?*

No, but the lorries must be convenient for the services to be done and several Railways prescribe that they must agree to their use beforehand.

— *Do you have any say in drawing up the itineraries?*

Except in Denmark and Greece, the contractor has complete freedom of choice.

— *Does a Railway employee go with the lorry?*

No, except in Greece.

— *To whom have requests to pick-up consignments to be addressed : the Railway or the contractor?*

On most Railways, both parties can be approached indifferently.

However, in Spain the consignor must approach the contractor, whereas in Greece and Luxemburg he has to ask the Railway.

— *Is a contractor allowed to run several lorry services, run other road services at the same time, or act as a transport agent?*

No Railway has raised any objections in principle, but they have all made certain reservations (see below).

— *What steps do you take to see that the contractor does not divert traffic from the Railway to his own benefit?*

All the contracts and agreements lay down that the contractor shall hand over to the Railway the whole of the traffic confided to him, and he cannot pursue any activities prejudicial to the Railway.

In addition, in Belgium he is required to limit his activities as a private haulier or transport agent to the services entrusted to him by the Railway.

The Railways consider that a control of these arrangements by the local services is sufficient.

— *How many haulage undertakings have you? Would it not be better to reduce the number by regrouping?*

The number of haulage undertakings conceded is considerable : 320 in Belgium, 269 in Denmark, 328 in Spain, 2 300 in France, 500 in Sweden, and 900 in Switzerland.

However there is usually only one contractor per locality or per station, and there is no point in regrouping the services, which would reduce competition, have an unfavourable effect on the

cost, and, it appears, meet a great deal of resistance.

Regrouping would only appear to be possible by reorganising the whole of the lorry services, as has been done in Italy and in part in France, or by the system of hiring lorries now being tried in Belgium. In Sweden, the creation of a subsidiary company is being considered, which will be the sole haulage firm acting for the Railway.

— *To what extent is the contractor responsible in the case of lawsuits, and how is the matter decided?*

The Railway alone is responsible to the public.

The haulier is in principle responsible to the Railway for loss and damage occurring during his work, unless he has pointed out discrepancies when taking over the goods.

Several Railways have agreed that in the case of internal damage, not verifiable, to the contents of parcels the responsibility shall be shared (half and half, or one third and two thirds).

QUESTION XVII. — *Have you in certain cases substituted road services for some of the old terminal services worked by collecting and distributing wagons?*

What advantages is there in this from the point of view of the customer and of the Railway?

Very few Railways have made such trials. Only Belgium, France and Sweden.

Sweden has not given any figures but states that it has been found advantageous in every way : reduced transit time and reduced operating costs.

In Belgium, 78 terminal road services covering 360 stations (30 % of the total number) have been organised. 32 of these services also cover door to door services. The traffic worked averages 370 tons a day, i.e. nearly 15 % of the total traffic, with an average output of 5.7 tons per working day for each lorry.

In France, the suburbs of Paris and Lyons and the Paris-Valence line are served by a mixed rail-road system organised in the following way :—

The suburbs of Paris have been divided up into 30 zones each depending on a central station or island-station. Transport is worked by means of lorries between the stations at the ends of lines and the island-stations. A lorry service has its starting point at each island-station and serves a given sector around this station.

Ten island-stations are now working very successfully. There is a saving of 24 to 48 hours in the transit time. On the other hand, although the rates have not been modified, the S.N.C.F. has made an appreciable saving in the wagon-days and train-km.

On the Paris-Valence artery, railway transport is now only worked between important centres. Road services are organised around these to serve the less important places.

Here again, no changes have been made in the rates, but substantial savings have been made in the train-kms. and in the train staff. Moreover the suppression of stopping parcels trains on a heavily loaded line has improved the train services on the line as a whole.

Generally speaking, it can be affirmed that on many lines the modifications considered are a paying proposition and the improvement in the services resulting therefrom will often attract customers to the Railway from other methods of transport.

QUESTION XVIII. — *How are the door to door services organised in the large towns?*

— *Are the headquarters of a lorry service at one or several stations; does*

each station serve the whole town or only certain districts?

In most cases there is only a single lorry service per town.

Only in Denmark, Sweden and Switzerland are there a few exceptions to this rule.

— *Are there separate lorry services for express parcels, luggage and postal packages?*

Certain Railways (Belgium, Finland, Norway and Switzerland) have organised special lorry services in the large towns for the express parcels service.

* * *

B. Concentration of the parcels traffic in a certain number of centre-stations, with rail transport between these centres, and road or rail transport between the place of consignment and the nearest centre-station, as well as between the last centre-station and delivery place.

Value of this method for the transport of goods.

Organisation of the centre-stations and the collection and delivery services.

QUESTION XIX. — *As things are organised at present, all the stations receive and dispatch their parcels traffic in through wagons.*

— *Do you not consider this method costly and complicated, both as regards staff and methods of traction, wagons, shunting and handling?*

Several Railways did not express any opinion, whereas those Railways with little traffic prefer to retain their present organisation.

Amongst the large Railways, only Italy expressed her intention of retaining the concentration of wagons towards transhipment stations, in view of the special configuration of the country.

Algeria, Belgium, Finland, France, Norway, Poland, Sweden and Switzerland are of the opinion that the present methods are costly from the above-mentioned points of view.

— *Does it meet the requirements of all the people served?*

In districts where there are no door to door services, is there any feeling of unjust treatment?

Although certain Railways think that the regions where there are no services have very little traffic, it is nonetheless true that the table (fig. 1) shows that in most countries a large proportion of the population (20 to 75 %) do not benefit by organised haulage services, which appears to be against the general interest.

QUESTION XX. — *Would it not be interesting, from every point of view, only to carry out transport by rail between a smaller number of carefully selected stations (centres) from which the parcels traffic could be distributed or to which it would be sent by road services which, in theory, would cover the whole of the country?*

Algeria, Belgium, France, Sweden and Switzerland are definitely in favour of this idea. Denmark, Italy, Norway and Poland are less certain, but admit that a partial reorganisation in this way would appear to be advantageous.

The suppression of pick-up and distributing wagons would lead to a great saving in staff and rolling stock, as well as in the fixed equipment in stations other than the centre-stations.

On the other hand, deeper penetration into the rural areas and into new places together with faster transport might bring new traffic to the railway.

QUESTION XXI. — *How do you select the centre-stations : according to their own traffic, their position on the main lines of the Railway (which facilitates and speeds up the turn-round of wagons), the roads, or other factors?*

Centre-stations should be sited as far as possible :

— at railway junctions of important lines to speed up the turn-round of wagons;

— at road junctions which are suitably sited from the point of view of lorry services to the different places in the sector, so that the journey times shall be about equal in every case;

— at points where there is important local traffic, taking into account the capacity and equipment of the station as well as the average radius of action;

— as a function of the other methods of transport of the locality (secondary railways, mail vans, etc.);

— according to the possibility of finding local contractors with sufficient appropriate vehicles;

— having regard to the situation and distance away of neighbouring stations.

QUESTION XXII. — *What in your opinion is the average sphere of action of the road services from a centre-station? Does this factor on which the number of centre-stations depends, take into account the amount of parcels traffic, the region served, the extent of the local road services, etc.?*

What do you think should be the minimum and maximum distances?

The sphere of action of a road centre should take into account :

— the density of the road network;

— the contours of the routes;

— the number of stations, places and depots on each circuit;

— the importance of the traffic of the places served;

— the staff available for handling the goods and the equipment available;

— the cost of rail and road transport.

The average figures quoted by the various Railways differ a great deal (from 10 to 100 km. [6 to 62 miles]) which is not to be wondered at, as circumstances differ a great deal from Railway to Railway.

It would seem possible to allow a minimum figure of 20 km. (12 miles) and a maximum of 50 km. (31 miles) according to the difficulty of the run.

To go below 20 km. generally means that the service will not be a paying proposition owing to the time the stock will be immobilised compared with the traffic; to exceed 50 km. would mean that the itineraries were too long to be properly worked without unduly tiring the driver, and the lorries badly used, as the mileage would be out of proportion to the tonnage carried.

QUESTION XXIII. — *Will not the organisation of centre-stations, thanks to the reduction in the number of consigning and receiving stations, increase the number of through wagons which can make the whole railway journey without any handling of the goods en route?*

What percentage of your parcels traffic do you think could be dealt with in this way?

What is the minimum load for through wagons?

All the Railways are unanimous as regards the increase in the number of through wagons.

The traffic which it is possible to transport by means of such wagons is estimated at 50 % or 70 % according to the Railway.

In the case of Belgium, a thorough investigation has shown that the figure

of 70 % can be allowed. Out of the whole of the traffic only 30 % of the goods have to be transhipped once; the remainder do not have to undergo any intermediate handling, apart from the change over from the lorry to the wagon at departure and from the wagon to the lorry on arrival.

This is an extremely interesting result, as transhipment is a very costly matter, apart from the loss of time and the risk of damage involved.

The minimum load laid down for through wagons varies from 2 to 4 t.

QUESTION XXIV. — *How do you deal with the routing between centre-stations :*

— *In the case of through wagons and goods loaded in other wagons?*

Through wagons travel by through train if possible between the centre-stations, or if this cannot be arranged via a marshalling yard, which is most often also a transhipment depot.

The other wagons are sent to transhipment depots from whence the goods, after shunting and regrouping, leave for the destination centre-station in through wagons.

— *Are you not of the opinion that the routing should be such that only one transhpiment is required in the case of goods which were not loaded into through wagons to begin with?*

This should be the aim, but the running of wagons with poor loads must also be avoided.

— *What transhipment equipment do you consider necessary?*

Transhipment is carried out in a very limited number of stations. As will be reported further on, only a few of these have to deal with any great tonnage and therefore require up-to-date equipment; night work is essential.

The other transhipment depots — the greater number — only have to deal with a relatively small amount of traffic (500 to 100 t. to be transhipped apart from local traffic), which does not involve any expensive equipment nor night work.

— *Can you state the average daily mileage of the parcels trains under this hypothesis?*

As no trials had been made of the new organisation in question, it was impossible to give any information on the subject.

An investigation carried out by the Belgian Railways showed that a reduction of 40 % in the tonnes-kilometres carried by the railway was likely.

QUESTION XXV. — *What are the advantages of setting up centre-stations : from the point of view :*

— *of transit time?*

The transit time will be appreciably shortened owing to the increase in the number of through wagons and the reduction in the number of transhipments?

of the user of the wagons?

The increase in the average load of the wagons and a more rapid turnround of the latter owing to their routing between a smaller number of stations will appreciably decrease the number of wagons required for parcels traffic.

In the case of Belgium, the saving will be more than 30 % (2 000 wagons used, including running light, instead of 3 000).

— *of the classification, formation and loading of the trains?*

The reduction in the number of destinations will simplify the formation of the trains, while the increase in transport by through wagons is bound to

have a good effect on the useful load of the trains.

— *of handling costs?*

These costs will be considerably lower, as the tonnage carried, according to the investigations of the Belgian Railways, should be reduced by two thirds.

— *of the facilities offered to clients?*

The possibility of delivering goods to all places served by road firms, i.e. over nearly the whole country, and of giving door to door services to most clients, must be considered a very important advantage.

— *of simplifying the rates?*

There can only be simplification if the railway rates are only applied for the journey between centre-stations, and most Railways are not in favour of this.

— *of additional traffic?*

The deeper penetration of road services into rural districts at present without services must necessarily draw new traffic to the railway.

This traffic will doubtless be relatively small. But the lorry is the only method of transport which can give such services economically.

This will improve the well-being of this portion of the population and may assist in the development of some of these localities from the industrial and agricultural points of view.

QUESTION XXVI. — *How do you consider centre-stations should be laid out from the point of view of the rail and road installations?*

It seems that the Railways have a tendency to regard the equipment of centre-stations as being on the same scale as that of transhipment depots.

This would appear to be an erroneous idea, as the tonnage to be handled does not usually justify very extensive equipment.

In Belgium, for example, where the density of the population is moreover the greatest in Europe, the total daily traffic (arrivals plus departures) at a centre-station varies between 10 and 80 tons, the average being 40 tons. Some dozen important centres, several of which will be chosen as transhipment depots, alone have a greater traffic.

In the case of the latter, the replies to question X give some useful information.

As regards centre-stations, the equipment can be relatively simple, especially as the traffic arriving and that leaving have not to be handled at one and same time. They must, it goes without saying, take into account the more important of the two traffics, and the multiple functions to be fulfilled : loading and unloading of wagons and lorries, local services (arrivals and departures), shunting of consignments according to destination of the wagons, on departure, according to the road sectors on arrival. As there are not generally many classifications, and the tonnage is relatively small, only ordinary means of handling need be provided : trucks hand-pushed or drawn by light tractors according to the importance of the centre-station.

A single platform suffices in most cases; the basic figures given in the replies to Question X can be used to determine its area.

Figure 15 shows a diagrammatic layout that has proved satisfactory. On the road side, part A of the platform is used for the local traffic brought to or collected from the station by customers; part B, proportional to the number of lorries used, is reserved for the traffic worked by the road services.

There need be nothing special on the railway side; the platforms need not be extensive, as the number of wagons arriving or leaving are not likely to exceed one dozen.

Finally work in the centre-stations is done entirely by day; loading operations will be completed about 9 p.m. while unloading will begin between 5 and 6 in the morning so that the lorries can be ready to start out between 8 and 9 a.m.

QUESTION XXVII. — *How do you organise the lorry services at centre-stations :*

— *yourself;*

— *by contract, method of payment, responsibility, steps taken to prevent traffic being taken away;*

— *waybills, accounts, receipts, door to door services, determination of the itineraries?*

All the Railways prefer to organise such services by contract.

Two methods of payment can be considered :

— according to weight and distance, as for ordinary lorry services;

— or hiring the lorries by the hour or the day, as described above, the latter being the most advantageous as it leaves the Railway in charge of the traffic from one end of the journey to the other, which avoids any risk of traffic being diverted to the road, maintains direct contact with clients, and simplifies the accounts with the contractor.

The first method makes it necessary to have a clause in the agreement with the contractor stipulating that all traffic that can go by rail shall be sent by rail, and to see that this clause is respected.

Responsibility will be divided as explained under Question XVI.

The waybills will cover the consignment from one end of the journey to the other, and all the rates charged will be paid to the Railway.

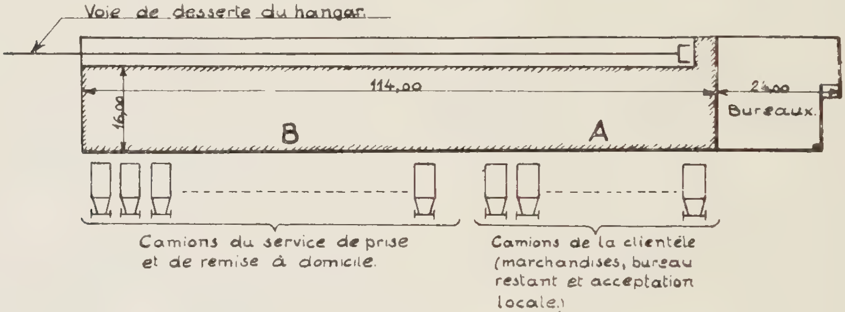


Fig. 15. — New goods depot at Bruges.

Explanation of French terms :

Voie de desserte du hangar = Service siding for the depot. — Camions du service de prise et de remise à domicile = Lorries for the door to door services. — Camions de la clientèle (marchandises, bureau restant et acceptation locale) = Lorries belonging to customers (goods, store and office for local traffic). — Bureaux = Offices.

The centre-station will keep the accounts for the receipts from its own local traffic and for the door to door services.

The stations served by road will deal with all the clerical work for the traffic worked by their intermediary.

Goods will be delivered home as far as possible; as for requests to collect goods, these may be addressed either to the contractor or to the Railway in

the first case, and to the Railway exclusively in the second case.

The itineraries will be determined by the contractor or by the Railway according to whether payment is made by the first or second method.

QUESTION XXVIII. — *Within the sector of a centre-station, is the local traffic (arrivals and departures) of the stations served by road dealt with systematically in the goods depot, or do you allow it to be dealt with in some private agency, selected in the centre of the locality served?*

Can such an agent be a private trader; how will he be paid and what are his responsibilities?

With the exception of Italy, the other Railways are in favour of the principle of an agency if the station is not in the centre of the locality.

The agent will be a grocer or « café » owner, known to be solvent and trustworthy, who can be depended upon for professional secrecy.

He will carry out the simple formalities (charges for small parcels and postal packages for example) and make himself responsible for seeing that the consignment reaches its destination. If he is connected by phone with the local station or centre-station, he can deal with all the charges, as in difficult cases he can ask the station. He will hand over all the receipts to the lorry driver against receipt together with a list.

He is paid either a fixed amount or so much per parcel.

His responsibility is that laid down by the law.

— *Cannot the use of agents make it possible to reduce the staff at the small and medium sized stations, for whom there is often insufficient work?*

It is usually considered that savings in staff will be small.

When the station is badly situated in respect of a town, the solution of an agency may however result in valuable savings in staff if the station can be closed to parcels traffic.

— *Will it not also give clients appreciable advantages as they will not have so far to go, as well as the Railways by shortening and simplifying its road services?*

The solution of an agency is considered advantageous for the Railway, but even more so for its clients who are often saved a great deal of time.

QUESTION XXIX. — *In sparsely populated districts, will not the cost of lorry services be prohibitive, especially door to door services.*

Would it not be better in such cases to consent to an increase in the transit time and adopt one of the following solutions :

— *limit the road services to 3 or 2 a week;*

— *or retain pick-up and distributing wagons, if necessary by using the secondary railway or some other method of transport?*

The Railways are of the opinion that :

a) in sparsely populated districts, door to door services should be rejected, except in the case of large consignments (minimum of 1 ton).

The creation of agencies will make such a restriction more acceptable;

b) an increase in the transit time due to limiting the road services to 3 or 2 a week is justified;

c) conveying goods to the terminal point by means of pick-up and distributing wagons, or better still by a van on goods trains or passenger trains or by postal or passenger motor coach, is to be recommended.

QUESTION XXX. — *How are the rates for consignments calculated :*

a) *usual rate for transit between the stations nearest the place of departure and arrival plus a charge for collection and delivery;*

b) *rate for transit between the centre-stations plus a special surcharge for the road journey to and from the centre-station; is the road charge standard within a given zone or proportional to the distance, for example concentric zones?*

Belgium, Denmark, Italy and Poland are in favour of solution *a*). Their opinion is justified by the need to maintain the rates at the present level and not expose clients to the difficulty of having to pay different rates every time it is thought better to serve a given district from a different centre-station.

Solution *b*) is preferred in Algeria, whereas France and Sweden are in favour of a combined solution : between places where there is a station, rates based on the railway rate for journeys between the two end stations; between places where there are no railway services, road rates exclusively, determined according to the distance and weight.

— *When are the rates for the road journey collected? How is the collecting and accounting organised?*

The Railways are generally in favour of sending goods carriage paid, the amount being collected by the lorry-driver, except in the case of clients with a credit account.

If the driver cannot decide what the rate should be, it is decided by the centre-station and collected by the driver on the following day.

The accounts are kept at the centre-stations.

QUESTION XXXI. — *If centre-stations are set up, how do you propose to deal with express goods and postal packages?*

If any such are received at a centre-station outside the normal hours at which the lorries are run, should they be dispatched by special lorry or passenger train? In the latter case, how are they delivered to the consignee?

In principle, the express goods and postal packages will be sent by passenger train between the centre-stations at the beginning and end of the route, and delivered home by special lorry or van.

Outside normal working hours, such consignments will go on by passenger train to the station nearest their destination which will be responsible for delivering them to the consignee, or will advise him of their arrival.

On certain Railways, postal packages are handled in the same way as parcels and sent by mail train to the centre-station which is responsible for delivering them to the consignee by the first normal lorry service.

* * *

C. Financial balance sheet.

QUESTION XXXII. — *Has your Railway carried out any investigations to determine in what cases and to what extent it pays to substitute lorry services for the railway services?*

Can you give a summary of the results of such investigations and the conclusions to which they have given rise?

Very few Railways have made any such investigations.

In Belgium, a thorough investigation has been carried out, a summarised account of which will be given at the end of this chapter.

France has drawn up a balance sheet for two trials carried out on its system :

— *in the suburbs of Paris,* the substitution of road services for the railway terminus services resulted in increased costs amounting to less than 10 % of the receipts, which is considered a very fair result in view of the *considerable* improvement obtained thereby as regards the transit of parcels;

— *on the Paris-Lyons-Valence artery,* the savings obtained were considerably greater than the additional cost, thanks to being able to do away with stopping trains and their staff.

In Poland and Switzerland, investigations are being made, but have not yet been concluded.

Sweden reports interesting savings obtained by introducing lorry services over a road network of some 1 000 km. (621 miles), but this is not a case of combined rail-road services.

QUESTION XXXIII. — *Have you set up any centre-stations on your Railway?*

If so, how are they organised, and how do the financial results compare with those obtained by the former organisation?

France is considering introducing road services in the Orleans and Chartres districts shortly. It will not be possible to draw up the financial balance sheet till these have been in operation for several months. It is not expected however that any saving will result, as it will not be possible to make any savings in the trains-kilometres. The object in view is an improvement in the quality of the service.

Belgium has already organised completely some 13 centre-stations out of a programme covering a total of 73. Amongst these 13, 4 are now working completely; in the 9 others, the local stations are served by lorry, but the door to door services, where there are any, are covered by local firms by agreements which it has not yet been possible to terminate, which involves an additional transhipment. The regrouping of these firms from each centre-station is in hand.

A financial balance sheet of any real practical value cannot be drawn up until all the centre-stations within the area of a transhipment depot are working; until this stage is reached, there cannot be any saving in the trains-kilometres.

It is however possible to state even now that from the point of view of the amount of traffic handed to the railway, there has already been a definite increase; the tonnage from the centre-stations to the stations of the corresponding sectors by 78 road routes has increased by 28 % and that of the door to door services by 40 %.

These very encouraging results show the interest clients feel in improvements to the service.

They also prove that the new organisation will make it possible to count upon recovering for the railway a considerable part of the parcels traffic now lost to the road.

Belgium has, moreover, drawn up a theoretical financial balance sheet which will be given later on.

The other Railways have not done anything in this connection.

QUESTION XXXIV. — *Have you made any financial investigations regarding the operation and equipment of transhipment depots and centre-stations?*

If so, please describe them and your conclusions.

All the Railways replied in the negative.

QUESTION XXXV. — *Have you made any costings for the different basic operations concerned in the transport of parcels traffic?*

In particular what is the cost : of the tonne-kilometre for wagons and lorries, of the loading or unloading of wagons and lorries per ton, of transhipment from wagon to wagon and lorry to lorry per ton, and of door to door services per ton?

The information received cannot be collated, since economic conditions vary so much from one country to another at the present time, and different factors or accessory costs are included in one or other of the costings.

It can however be affirmed that approximately :

— the lorry tonne-kilometre costs 2 to 5 times more than the wagon tonne-kilometre;

— loading, unloading, or the transhipment of goods costs are approximately the same whether it is question of lorries or wagons;

— the handling of goods, including formalities on acceptance and delivery, shunting, etc., are extremely costly compared with the cost per tonne-kilometre : on the average 50 to 60 times as great;

— the cost of door to door services per ton, which varies from one Railway to another, is however very high in every case; it costs 50 to 150 times as much a lorry tonne-kilometre.

QUESTION XXXVI. — *Do you consider that the organisation of centre-stations is likely to reduce the amounts paid as compensation for delays, losses, theft, and damage, and to what extent?*

The total amounts paid as compensation for delays, thefts and damage is of the order of 4 to 5 % of the receipts.

All the Railways agree that a reorganisation of the traffic by means of centre-stations should appreciably reduce this amount, owing to the decreased intermediate handling.

It is not however possible to estimate the amount of this reduction without practical trials.

* * *

An investigation into the organisation of the parcels traffic on the Belgian railways by means of centre-stations.

Before concluding, it appears to be of interest to give a brief summary of the theoretical investigation carried out in 1946 by the Technical Operating Services of the Belgian Railways in order to determine the most favourable method and financial value of reorganisation in this way.

Although based on average figures for the traffic and costs, this investigation gives some very valuable information making it possible to base the new organisation upon formal mathematical elements and not on mere opinions which must be judged with caution.

It appears to afford a starting point for similar investigations on other Railways.

1) *Principles of the organisation.*

The organisation is as follows :

— the railway is divided up into a certain number of zones (to be determined) each with a transhipment depot;

— amongst the transhipment depots, one depot (Brussels) is the principal, the others secondary;

— each zone includes a certain number of centre-stations (to be determined); the transhipment depots also function as centre-stations;

— each centre-station serves a well defined district or sector by means

of road services; on consignment, goods are collected by lorry from the station depots, agencies or consignor's premises;

— on departure from a centre-station C_1, the goods are given the following routing with 0 or 1 intermediate transhipments :

a) by through wagon W to another centre-station C_n (fig. 16) if traffic for this station reaches a sufficient level (3 tons);

b) to the secondary transhipment depot t_1 of the zone if the centre-stations for arrival and departure belong to the same zone;

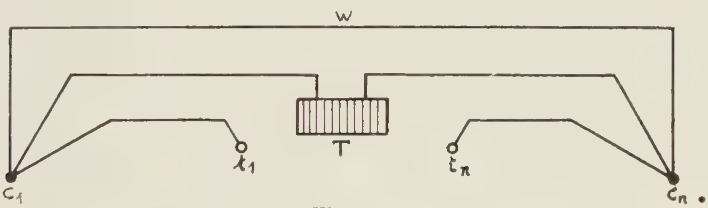


Fig. 16.

c) to the main transhipment depot T if the departure and arrival centre-stations belong to different zones.

— from the transhipment depots, goods travel to the centre-stations of their destination exclusively by through wagon;

— on arrival at the centre-stations, the goods are sent by lorry to the stations or depots of the district, or delivered home, on the inverse processus to that applied at departure.

2) *Determination of the optimum number of centre-stations.*

This determination is based on the following statistical formulae and elements :

a) *Relation between the number of centre-stations and the average tonnage between two centre-stations.*

Let : T be the tonnage received daily over the whole railway,

n the number of centre-stations,

t the average daily tonnage between two centre-stations.

The average tonnage accepted in each centre-station $= \dfrac{T}{n}$

This tonnage is divided up in theory between n centre-stations; the average traffic t between two centre-stations :

$$t = \frac{T}{n} : n = \frac{T}{n^2} \quad (1)$$

b) *Relation between the number of centre-stations and the mileage run by the lorries.*

It can be admitted that the mileage run by the lorries is proportional to the lineal dimensions of the sector served, i.e. to the square root of its surface.

On the other hand, the surface of the sector is inversely proportional to the number of centre-stations.

If L is the radius of service, we can write :

$$L = \frac{c}{\sqrt{n}} \quad (2), \ c \text{ being a constant.}$$

The *average distance covered*, if the traffic is uniformly distributed throughout the sector, is equal to $^2/_3$ of the radius of action.

In practice the centre-station being organised in a locality with heavy traffic, it can be admitted that the average

distance is equal to half the radius of action.

c) *Cost of the different basic operations.*

After chronometrical tests and calculations based on the wages and cost of raw materials in 1947, the cost of the various basic operations which affect the cost of combined rail-road transport can be established.

Owing to lack of information regarding the accountancy services, these figures only cover the cost of handling and transport, excluding general costs, the cost of acceptance and charging, etc. This entails no drawbacks since the investigation is into the difference of cost of various organisations for which the factors left out of the picture can be considered as a constant.

It must not be forgotten however that the costs given are not the total costs.

Transport by rail	0.926 fr. per tkm.
Transport by lorry	2.46 fr. per tkm.
Loading onto wagon (1)	59.50 fr. per t.
Unloading from wagon (1)	63.80 fr. per t.
Transhipping from wagon to wagon (1)	72.70 fr. per t.
Loading or unloading from lorry (2)	21.75 fr. per t.
Transhipment from lorry to lorry (1)	54.30 fr. per t.
Transport by lorry including loading and unloading (services to stations and depots)	43.50 + 2.46 L. per t.
Door to door services	300 + 2.46 L. per t.

d) *1938 traffic statistics.*

The investigation was based on the 1938 traffic, which was the last normal year for parcels traffic.

The first abstract completed with the hypothesis of an arbitrary choice of 84 centre-stations and 8 transhipment depots gave the following results :

Daily tonnage leaving	3 353.5 t.
Traffic from the 84 centre-stations (arrival and departure), stores and local consignments	2 322 t.
Door to door services	1 676 t.
Tonnage from stores and local consignments (arrival and departure) from the other stations and depots = (3 353.5×2) — (2 322 + 1 676) =	2 709 t.
Average radius of services from the centre stations	20 km. (12 miles)
Net daily tonnes-kilomètres	313 272 tkm.
Average mileage of through wagons	81.5 km. (50½ miles)
Tonnage to be handled daily at the transhipment depots	1 115 t.
Average load of wagons	3.4 t.

(1) Cost includes shunting operations and classification of the parcels.

(2) Cost does not include the operation included under (1).

e) *Minimum number of centre-stations.*

The minimum number of centre-stations is attained when all the transport can be carried out by means of through wagons between the centre-stations, without any goods having to be transhipped.

This number is given by the formula (1) for $t = 3$ tons. In this case it can be deduced :

$$n = \sqrt{\frac{T}{t}} = \sqrt{\frac{3353.5}{3}} = 33.$$

This number differs appreciably from the actual figure, owing to the fact that a very considerable proportion of the traffic is concentrated in the large towns.

In Belgium, the towns of Brussels, Antwerp, Liege, Ghent and Charleroi together are the origin of $^2/_5$th of the total traffic. Leaving aside this tonnage and that accepted in the other centre-stations for the 5 places in question, there remains a traffic of 1 220 tonnes.

As a result the number of centre-stations is :

$$n' = \sqrt{\frac{1220}{3}} = 20.$$

Adding the 5 large centres mentioned above, the minimum number of centre-stations is :

$$n_m = 20 + 5 = 25.$$

This figure is obviously only an approximation since it supposes that the traffic is equally distributed amongst the 20 centre-stations n'.

f) *Number of transhipment depots.*

It can be admitted that the total tonnage to be transhipped is independent of the number of secondary depots; it depends essentially on the number of road sectors, i. e. on the number of centre-stations.

The number of depots only affects the average distance of rail transport which increases as the number of depots decreases.

Let : T_r be the total tonnage to be transhipped,

q the number of transhipment depots,

n the number of centre-stations.

Amongst the consignments leaving the centre-stations of a given zone, $\frac{T_r}{q}$ tonnes on the average will have to be transhipped.

Of these $\frac{T_r}{q}$ tonnes, only $1/q$th is consigned to the centre-stations of the same zone, i.e. $\frac{T_r}{q^2}$ tonnes to be transhipped per depot.

If the central depot is excepted, the total to be transhipped in the secondary depots is $t_r = \frac{T_r(q-1)}{q^2}$. A check on surveying the case of the 84 centre-stations has shown that this formula, based on the average figures, is rather far from the truth, and it is better to put :

$$t_r = \frac{1.5T_r(q-1)}{q^2} \quad (3).$$

On the other hand, each zone includes $\frac{n}{q}$ centre-stations on the average.

The average load C of the wagons running between the centre-stations and the secondary depots should therefore be :

$$C = \frac{t_r}{\frac{n(q-1)}{q}} = \frac{1.5T_r(q-1)}{\frac{n(q-1)}{q} \cdot q^2} = \frac{1.5T_r}{nq}$$

Fig. 17. — DAILY C

Number of centres	Radius of services in km.	Average distance covered in km.	Road Services						
			Traffic accepted and handed in locally.				Door to door servi	
			from the stations in t.	from the depots in t.	Cost of lorry transport in Frs.		Tonnes	Cost
					per tonne	Total		per tonne
1	2	3	4	5	6	7	8	9
84	20	10	2 322	2 709	68.10	184 500	1 676	324.60
70	21	10.5	2 244	2 787	69.43	194 000	»	325.93
60	23.7	11.8	2 140	2 891	72.53	209 000	»	329.03
50	26	13	2 023	3 008	75.98	227 000	»	331.80
40	29	14.5	1 882	3 149	79.27	249 000	»	335.77
30	33.5	16.8	1 755	3 276	85.03	278 000	»	341.53
20	41	20.5	1 527	3 504	91.03	319 000	»	350.53
0	—	—	—	—	—	—	»	300.00

To obtain proper user of the stock it is necessary to have

$$C > 3 \text{ tonnes}$$

whence $$\frac{1.5T_r}{nq} > 3$$

and $$q < \frac{T_r}{2n} \quad (4).$$

g) *Optimum number of centre-stations.*

With the statistic data and theories developed above as a basis, it has been possible to find the cost of parcels traffic for various numbers of centre-stations from 20 to 84, without having to make any analysis and detailed calculations for each hypothesis of the number of centre-stations.

The calculations are summed up in the table (fig. 17).

The various numbers given in this table have been obtained as follows :

Columns 2 and 3 : by application of formula (2).

Column 4 : from statistical data, for the centre-stations envisaged in each case.

Column 5 : from the difference between the total traffic (arrivals plus departures) i.e. 2 × 3 353.5 = 6 707 and the numbers in column 4.

Column 6 : by application of the formula for the cost of transport by lorry (43.50 plus 2.46 L).

Column 7 : by multiplication of the numbers in columns 5 and 6.

…ANEOUS GOODS TRAFFIC.

		Railway Services						
…ed …rry …ost	Total cost of operations covering lorry transport	Tonnage loaded (or unloaded) into lorries	Cost of loading	Cost of unloading	Cost of transhipment	Cost of rail journey	Total cost of operations covering rail transport	Total cost of the miscellaneous goods services
…2	13	14	15	16	17	18	19	20
…170	730 670	3 314	197 000	211 500	81 000	291 000	780 500	1 511 170
…600	742 600	3 306	196 500	211 000	63 000	279 100	749 600	1 492 200
…040	763 040	3 298	196 000	210 500	50 400	271 280	728 180	1 492 220
…630	786 630	3 286	195 500	210 000	37 800	263 460	706 760	1 493 390
…550	815 550	3 270	194 500	209 000	25 200	255 640	684 340	1 499 890
…070	854 070	3 242	193 000	207 500	12 600	248 820	661 920	1 515 990
…050	915 050	3 186	191 500	203 500	—	241 000	636 000	1 551 050
—	503 000	3 354	199 000	214 000	244 000	485 000	1 142 000	1 645 000

Column 8 : tonnage of door to door services (given under *d*) above).

Column 9 : by application of the formula for the cost of door to door services (300 plus 2.46 L).

Column 10 : by multiplication of the numbers in columns 8 and 9.

Column 11 : It is question of the tonnage from and to a point within the sector of one and the same centre-station. It is equal on the average to

$$\frac{T}{n} \text{ or } \frac{3353.5}{n}.$$

Column 12 : multiplication of the numbers in column 11 by the unit cost price (54.30 fr.).

Column 13 : sum of the numbers in columns 7, 10 and 12.

Column 14 : difference between the total tonnage (3 353.5) and the numbers given in column 11.

Columns 15 and 16 : multiplication of the numbers in column 14 by the cost of the corresponding operation.

Column 17 : with 84 centre-stations, the tonnage to be transhipped is 1 115 t.; with 20 centre-stations (to be on the safe side 20 were allowed instead of 25), this tonnage is nil;

for the intermediate numbers, the lineal interpolations are shown;

the unit cost price of the operation has been applied to the numbers obtained (72.70 fr.).

Column 18 : with 84 centre-stations, the number of tonnes-kilometres by rail

is 313 272 and the cost 313 272 × 0.926 = 291 000 fr.;
with 20 centre-stations the number of tonnes to be carried by rail $= T - \frac{T}{n}$ = 3 186.
With the same average mileage, the number of tonnes-kilometres = 3 186 × 81.5 = 259 600 and the cost = 259 600 × 0.926 = 241 000 fr.
Intermediately, lineal variation.

Results of the investigation.

It is found that the total minimum expenditure corresponds to a number of centre-stations between 60 and 70.

It is about 10 % lower than that of a service organised without centre-stations : therefore the saving that can be expected from the new organisation is of this order.

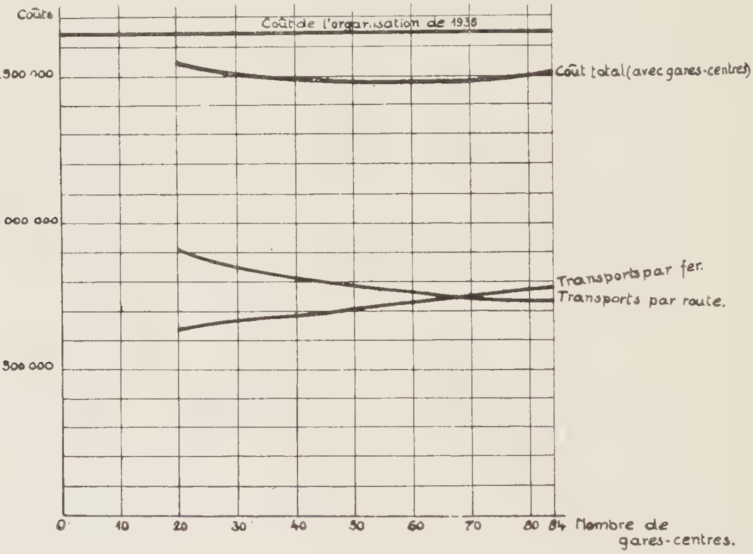


Fig. 18.

Explanation of French terms :

Coûts = Costs. — Coût de l'organisation de 1938 = Cost of the 1938 organisation. — Coût total (avec gares-centres) = Total cost (with centre-stations). — Transports par fer = Transport by rail. — Transports par route = Transport by road. — Nombre de gares-centres = Number of centre-stations.

Column 19 : sum of the numbers in columns 15, 16, 17 and 18.

Column 20 : sum of the numbers in columns 13 and 19.

Remark : If there are no centre-station, the cost of an organisation in which all the transport is worked by rail, except for the door to door services, is obtained.

This was the organisation in force on the Belgian Railways in 1938.

The fairly great amplitude of this level, which is brought out by figure 18 showing curves representative of the cost of transport by rail, by lorry and the total cost for various numbers of centre-stations, is very favourable from the practical point of view. It makes it possible in fact to adapt the organisation to geographical and local circumstances without affecting appreciably the cost of the organisation.

In the case of the Belgian Railways, this has led to the conclusion that 73 centre-stations, the sectors of action of which are shown in the map given in figure 19, should be adopted. The parts of the country not attached to a lorry service district are wooded regions served by a secondary railway.

Formula (4) which gives the maximum number of transhipment depots gives in this case :

$$q < \frac{1115 \times \frac{73}{84}}{2 \times 73} \text{ or } 6.6$$

in which $q = 6$, i.e. 1 chief depot and 5 secondary depots.

Dealing with the amount of traffic per station, it was found that the 6 most important centre-stations dealt with about 50 % of the total traffic of the system, and the 25 principal centre-stations nearly 80 % of the total traffic.

Consequently these 25 stations were the ones to be reorganised first of all.

The tonnage to be transhipped at the main depot and in the secondary depots can be determined by applying formula (3) : this gives a figure of 750 t. for the main depot and 250 t. for all the 5 secondary depots, i.e. an average of 50 tons for each of them.

As a result only the main depot will be of any real importance, since its transhipment traffic of 750 t. will be additional to the local traffic, i.e. 500 t. approximately. Night work will be essential in this depot if the transit time is not to be unduly prolonged. It will also be justified by the necessity of dealing separately with local traffic and transhipment traffic if the installations are not to be extended.

On the other hand, in the secondary depots, it will be possible to break off work from 11 p.m. to 5 a.m. without any inconvenience. This is of undoubted social advantage, since before the war night work was usual in all the transhipment depots.

The local traffic of these secondary depots varies between 100 and 400 t.

Apart from these 6 station depots, only 19 have to deal with traffic amounting to between 50 and 90 t., while the traffic of the remainder lies between 10 and 40 t. which does not involve any costly installations or equipment.

The lorry services at the important centres will continue to be run by the railway itself.

At the other centre-stations on the contrary preference will be for contract work, probably by hiring lorries, a practice which has undoubted advantages.

In a few rare cases where the traffic is insufficient to justify road services, the consignments can be sent by a wagon or van on a goods train, by secondary railway or passenger coach when such are available.

Conclusions.

1. Parcels traffic is generally sent by through wagon and by wagons serving various purposes (collecting, distributing, transhipment, line, etc.).

Having regard to the cost of handling, everything is in favour of an organisation which reduces the latter to the minimum possible.

This is achieved when the number of through wagons is the maximum. Good utilisation of the stock makes it necessary to prescribe a minimum load (3 or 4 tonnes).

2. A comparison of the receipts and tonnes-kilometres for parcels traffic and complete loads makes one suppose that the rates are not based on the actual cost.

Any organisation of parcels traffic necessarily includes a division of the transport between rail and road, so that

Fig. 19. — S. N. C. B. Parcels traffic. Plan of the proposed centre-stations.

Explanation of French terms :

- 6 important centre-stations (more than 100 t. daily, arrivals and departures) 50 % of the total traffic of the system.
- 19 medium sized centre-stations (from 100 to 50 t. daily, arrivals and departures) 30 % of the total traffic of the system.

it is important to see, in the general interest, that such a division is based on the cost of each kind of transport.

With this object in view, it is to be recommended to the Railways to ascertain the cost of each kind of transport.

3. Road transport undertakings are not subjected to the same obligations as railway undertakings from the point of view of destination, kind of goods and rates.

It is imperative to see that everything is done to put the two methods of transport on an equal footing from this point of view, as far as is technically possible.

Whilst leaving the consignor free to select the method of transport best suited to his requirements, the homologous rates offered should be an exact reflection of the actual cost of each kind of transport, these rates being established on the same basis taking into account amortisation charges, and maintenance and operating costs.

4. The part played by transport grouping agents is advantageous for the Railways in the sense that they reduce the amount of handling and improve the efficiency of the stock thanks to the formation of complete wagon loads.

The rating benefits generally allowed to transport agents must however be granted in conjunction with a guarantee by the latter that they will limit their activities to the sector given them by the Railways and will send by rail all the consignments that can go by rail.

The same undertaking should be required of all private lorry owners working on behalf of the Railway.

5. The concentration of the parcels traffic in a certain number of centre-stations with railway transport between such stations and road transport between the centre-stations and the consigning centres on the one hand and the place of delivery on the other, is likely in most cases to reduce operating costs whilst reducing the transit time and reaching a greater proportion of the population.

This method is of value both in the general interest of the population and from the economic point of view.

When rationally conceived in terms of the cost of each kind of transport, the new organisation will be in fact a first step towards the co-ordination of rail and road.

6. The choice of the centre-stations will be influenced not only by the cost, but also by the position of the stations on the lines (railway junctions) to facilitate and speed up the turn-round of wagons between the centre-stations, owing to their situation in relation to the road network and the importance of the local traffic.

A certain number of centre-stations will be selected as transhipment depots.

Some of them (principal) can deal with the traffic from any zone, the others (secondary) with the internal traffic of their own zone and that of a certain number of neighbouring zones.

Goods will travel by through wagon in every case, as far as possible from centre-station to centre-station, or if this is not possible through one or a maximum of two transhipment depots.

7. Only the principal transhipment stations will have a large amount of traffic to handle.

According to the importance of this traffic, the stations will be provided with platforms, or not.

The reduction in the transit time will generally mean that such stations will have to work at night.

The traffic of the secondary transhipment stations will not be sufficient to justify important installations, unless the local traffic is particularly heavy. Night work will be exceptional.

8. For the organisation of the road services from the centre-stations, a solution is to be preferred which will avoid any loss of traffic to the road, and will maintain direct contact between the Railway and its clients.

When the Railway cannot work its own lorry services, the possible choice lies between an affiliated company using local resources to some extent or entirely, and the hiring of lorries from private firms in the district.

In cases where certain stations served by road lie at some distance from the towns or when it is question of rural districts with a scattered population, it may be valuable, both for the Railway and for its clients, to set up agencies with firms in the centre of the district.

9. If the traffic in some sectors is very small, the number of weekly services can be reduced to 3 or 2, or existing methods of transport can be used which can carry the goods without additional expense (vans on passenger trains or goods trains, secondary railways, bus services).

10. From the point of view of the rates, two solutions are possible :

— the railway rates can be applied between the departure and arrival stations, and the cost of the door to door services added if necessary;
— or railway rates can be applied only between the centre-stations, and road rates for the transport worked by lorry.

The first solution has the advantage of stability, whereas the second comes nearer to the real cost of the transport and simplifies the rates and accountancy.

In any case the road rates should take into account both the weight of the consignment and the distance it is transported.

[621 .335]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

ENLARGED MEETING OF THE PERMANENT COMMISSION
(LISBON, 1949.)

QUESTION II.

Electric locomotives for fast trains (75 m.p.h. and over). Discussion of adopted and projected types.

1) Arrangement of the axles.

2) Type of axle drive :

a) motor suspended from the nose;

b) flexible transmission.

3) Electric motor characteristics.

4) Braking.

REPORT

(Austria, Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburg, Norway, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Jugoslavia),

by Dr. E. MEYER, and Ch. STHIOUL,

Ingénieur en Chef Adjoint de la Division de la Traction et des Ateliers de la Direction générale des Chemins de fer fédéraux suisses, à Berne.

Ingénieur, Chef Adjoint de la Division de la Traction du 1er Arrondissement des Chemins de fer fédéraux suisses, à Lausanne.

INTRODUCTION.

The present report gives particulars of electric locomotives for high speed trains (75 miles per hour and over) in use in the European Countries and their Colonies with the exception of Great Britain and Russia. A detailed questionnaire was sent to 95 Railways in these countries.

From the 42 replies received the following countries have no main line electrification :

Bulgaria, Denmark, Finland, Greece, Luxemburg, Portugal, Rumania, Turkey and Jugoslavia.

Others with electrified lines have no high speed electric locomotives in service or under construction. These are :

Spain, Norway, Poland and Czechoslovakia.

This report, therefore, is based on the replies received from Germany (*), Austria, Belgium, France, Hungary, Italy,

(*) Personal information of the Reporters.

Holland, Sweden and Switzerland. It relates to electric locomotives for high speed trains actually in use and under construction in the countries mentioned and shown in Table I, which gives the leading characteristics.

We feel it would be of interest to complete the subject by going beyond the questions submitted to us.

The subject matter of this report is dealt with under the following headings:

Chapter I.	General considerations.
Chapter II.	Types adopted for high speed locomotives.
Chapter III.	Mechanical parts.
Chapter IV.	Driving of the axles.
Chapter V.	Brakes.
Chapter VI.	Traction motors and particulars of electrical equipment.
Chapter VII.	The behaviour of the locomotives in service at high speed.

The figures in brackets in the report are the numbers in numerical order of the locomotives to which the text relates, as shown in Table I.

CHAPTER I.

General considerations.

Increase in train speeds and the consequences.

For a long time 120 km. (75 miles) an hour was considered the maximum speed for trains hauled by locomotives. Even today, this limit is not exceeded, in fact not reached, in many countries. As a result of increasing road competition, many Railways have introduced light fast railcars with which the usual speeds could be exceeded. These vehicles, though much appreciated on account of their high average speed, were not large enough in many cases. This fact gave rise to a desire to be able to run trains hauled by locomotives at much higher speed. In consequence, a number of electric locomotives have been built for speeds exceeding 120 km. an hour.

Whereas some Railways (Austria, Belgium, Hungary and Switzerland) are satisfied with speeds of 125 km. or 130 km. (77 or 80 miles) an hour as a maximum, France, Italy and Holland built locomotives for speeds of 150 km.-160 km. (93 and 100 miles) an hour. The German locomotive E.19 was built for a maximum speed of 180 km. (112 miles) and even 220 km. (136 miles) an hour. These differences may be due to the particular conditions of the different systems. They also show that opinions are strongly divided on the question of knowing to what extent an increase in the maximum speed is technically possible and ecomonical. At the present time only in Switzerland, and to some extent in France, are the maximum speeds for which the locomotives were built (120 km. and 125 km.) being run in regular service. Speeds exceeding 140 km. (87 miles) an hour have not yet been run in regular train workings with locomotives in any European country.

The increase in the maximum speed of the trains raises various technical and economical questions, which did not arise when fast railcars were introduced or were then much easier to solve.

To begin with it must be remembered that lines with many sharp curves do not lend themselves to high maximum speeds. Whereas curves of 800 m. (2 624′8″) can be run through at 120 km. an hour, when the speed is raised to 180 km. an hour the radii of the curves must be at least double. There are many countries with straight sections or with curves of large radius on which there is nothing to stop the speed being raised. The permanent way must be capable of supporting the higher loadings caused by the greater speeds. In many cases the safety installations must

be adapted to the higher speeds and altered to meet the greater danger resulting therefrom. From this point of view all demands can now be met technically.

The same thing can be said of the locomotives and carriages. It is possible today to get stock and equipment of the necessary quality to meet all demands so that any increase in speed will not decrease safety at all nor the comfort of the passengers and staff. High speeds will require greater power. With electric traction there is no difficulty in installing the necessary motive power in relatively simple locomotives. The E.19 locomotive weighing 113 tonnes (111.215 Engl. tons) (7) is able to work a train of 360 tonnes up gradients of up to 3 $^0/_{00}$ at 180 km. an hour whilst developing some 5 500 H.P. Under the same conditions two of these locomotives ought to be able to haul the heaviest high speed trains should it be advisable to do so with trains made up to such a length and weighing so much.

In the case of such locomotives, there is no difficulty in the supply of current from the overhead wire with alternating current of 15 to 20 kV. even when double headed. In the case of double heading with 1 500 V. D. C. there are some problems but they are not insolvable.

The pick up of current from the contact wire becomes more difficult as the maximum speed is increased. So far it appears that no satisfactory solution has been found for speeds over 140 km. an hour. The solution would appear to be more difficult with the light wires with alternating current than with the heavier and more stable wires with direct current. The high speeds require the contact wires to be very carefully adjusted. It is also essential that the roof of the locomotive and the equipment on it should be streamlined so as to reduce to a minimum the wind effect when running on the wire.

The most difficult problem increased speed gives rise to is undoubtedly that of braking. As a rule the stopping distance should not exceed 1 000 m. (1 093 yards). To get this, when taking into account the influence of rotating masses, the drivers time to react, and the time for the brake to act, the average brake force needed is 61 kgr. per tonne (136 lbs. per Engl. t.) of axle load at 120 km. (74 miles) per hour and 142 kgr. per tonne (318 lbs. per Engl. t.) at 180 km. (112 miles) per hour. In the latter case the limit of adhesion is almost reached so that such brake power is only possible with equipment with automatic devices regulating the block pressure to suit the frictional conditions. Such equipment (such as the Knorr antiskid device) already exists and if these are inadequate to get the needed stopping distance electro-magnetic rail brakes already in use can be used in addition. The absorption of the energy produced during braking is not difficult. This energy increases with the square of the speed and shows itself mainly in the form of heat, except when returned to the wire in the case of locomotives with regenerative braking. The fact that this energy is produced the more rapidly the higher the speed aggravates the matter. In fact, to get the same stopping distances, the brake power grows almost to the third power with the speed. When starting to brake at 120 km. an hour it rises to about 20 kW. per tonne and reaches about 70 kW./t. at 180 km./h. This means not less than 33 000 kW. for a 360 tonne train hauled by an E.19 locomotive. How can so much power be dissipated without damage to the tyres and other parts? This is indeed the greatest problem raised by the increase in speeds and has not been solved satisfactorily yet.

The above review shows that in spite of the great possibilities of present day technique, there is a limit to the increase in the speed of trains. It is hardly pos-

TABLE I. — LEADING CHARACTERIST

Serial Number	Country	Railway	Type	Date first locomotive put into service	Number of locomotives	Maximum service speed	1 hour ra… Power
(1)	(2)	(3)	(4)	(5)	(6)	(7) km./h. and m.p.h.	(8) H.P.
1	*France*	SNCF	2' Do 2'	1926	107	130 (80)	3700
2	»	»	»	1934	18	120 (74)	4590
3	»	»	2' BB 2'	1935	6	130 (80)	4290
4	*Italy*	FS	2' BoBo 2'	1934	237	130 (80)	3800
5	*Germany*	DR	1' Co 1'	1934	23(1)	130 (80)	2970
6	»	»	1' Do 1'	1935	61(1)	140 (87)	4120
7	»	»	»	1939	2(1)	180 (112)	5430
8	»	»	»	1940	2(1)	180 (112)	5550
9	*Austria*	OeBB	»	1940	7	130 (80)	4800
10	*Switzerland*	CFF	»	1941	6	125 (77)	5540
11	»	»	(1Ao)Bo(Ao1)	1944	6	125 (77)	5540
12	*Sweden*	SJ	1' Do 1'	1942	24	135 (89)	3500
13	*Netherlands*	NS	(1Ao)Bo(Ao1)	1948	10	160 (100)	4480
14	*Italy*	FS	Bo' Bo'	1943	153	140 (87)	2160
15	*Switzerland*	BLS	»	1944	4	125 (77)	4000
16	»	CFF	»	1946	50	125 (77)	2450
17	*Belgium*	SNCB	»	being built	3	125 (77)	2700
18	»	»	»	»	3	130 (80)	2800
19	*Hungary*	MAV	Bo' Co'	»	2	125 (77)	3200
20	*Italy*	FS	Bo' Bo' Bo'	1939	117	140 (87)	3240
21	*France*	SNCF	Co' Co'	being built	2	150 (93)	3300(2)

(1) Estimated. — (2) Power at continuous rating.

IC LOCOMOTIVES FOR HIGH SPEED TRAINS.

nt	Length over buffers	Wheelbase		Diameter of wheels		Weight per H.P. (1 h. rat.)	Kind of current	Number of motors	Gear ratio
Adhe-sive		Total	Rigid	Driving	Carrying				
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
t.	m. (=3'3 3/8'')	m. (=3'3 3/8'')	m. (=3'3 3/8'')	mm. (= 3/64'')	mm. (= 3/64'')	kgr./ch. H.P.			
80	17.78	14.40	6.06	1750	970	35.7	=	4	1:2.55
80	17.78	14.40	6.06	1750	970	28.4	=	4 × 2	1:3.33
80	17.78	14.40	6.06	1750	970	30.4	=	2 × 3	1:3.15
75	19.00	15.90	2.35	1880	1100	35.3	=	8	1:3.26
61	15.12	11.60	6.00	1600	1000	31.0	~	3	1:2.93
78	16.92	12.80	7.20	1600	1000	26.2	~	4	1:2.79
81	16.92	12.80	7.20	1600	1000	20.8	~	4	1:1.90
82	16.92	12.80	7.20	1600	1000	20.0	~	4 × 2	1:3.44
79	16.92	12.80	7.20	1600	1000	23.2	~	4	1:2.94
79	17.26	12.20	3.20	1350	950	19.0	~	8	1:3.22
79	17.26	12.20	3.20	1350	950	19.0	~	8	1:3.22
69	15.50	11.60	6.86	1530	980	29.2	~	4	1:3.35
72	16.22	11.89	2.23	1550	1100	22.3	=	8	1:3.57
72	15.50	10.50	3.15	1250	--	33.3	=	4	1:3.10
80	15.60	11.50	3.25	1250	—	20.0	~	4	1:2.22
56	14.70	10.80	3.00	1040	—	22.8	~	4	1:2.85
80	17.19	12.00	3.50	1262	—	29.6	=	4	1:3.26
81	16.30	11.60	3.60	1350	—	28.9	=	4	1:2.05
85	14.60	10.30	3.50	1036	—	26.6	~ (50)	5	1:3.27
101	18.25	13.50	3.15	1250	—	31.2	=	6	1:3.10
98	18.83	14.14	4.845	1250	—	29.7(2)	=	6	1:2.61

sible to say where this limit lies. We need no try to prophesy on the subject as we are convinced it is not a *technical* matter but rather an *economic* question.

Generally speaking there is no answer to the question of the economic limit of increased speed. It depends much more on the present constitution of the particular Railway than on technical conditions. It is no deception to say that the maximum speed dictated by economic reasons will be lower than that due to mechanical difficulties.

An increase in the maximum speed necessitates, amongst other things, a heavy capital investment to improve the location of the track (elimination of small radius curves), the strengthening of the bed, the modification of safety devices and improvements in the overhead wire. In many cases high speed transport over rail even involves the construction of new lines. The motor and trailer vehicles for high speeds are costly as they have to be equipped with additional equipment and with high power machinery. In high speed service too the fixed plant and the rolling stock require more maintenance so that to the higher installation costs higher operating costs have to be added. On account of the greater resistance to forward movement at high speeds and the greater losses due to more frequent and more severe braking, the specific expenditure of energy increases considerably with the running speed. The result of these factors is to make an increase of speed over a certain limit although technically speaking quite possible, so costly that it cannot be considered economic. These financial considerations, therefore, place a limit more or less high on the increase of speed according to the structure of the present railways. For example, when the matter was investigated on the Swiss Federal Railways (C.F.F.) it was found that the maximum economic speed was 125 km. an hour. There were sections over which higher speeds were possible but they were too short for high speed to be held any length of time or before the acceleration period was ended it was time to brake to reduce speed for the next curve. The improvement in journey time so obtained was particularly small : it was not in proportion to the increase in cost for altering the fixed installations and the rolling stock to suit the higher speed nor to the increased maintenance, the greater consumption of energy, and the greater rate of wear of brake blocks and other parts involved. The maximum economic speed can be very much higher in other cases in which the lines have fewer curves and the gradients are less severe than in Switzerland. From the economic aspect the increase of speed is not likely to exceed 150 km. (93 m.)/h. in the near future.

Another method most suitable for increasing the commercial speed of trains is to raise the speeds through curves. On a line with many curves this method reduces the journey time much more than any increase in speed.

Permissible speeds through curves are fixed in the Regulations by the formula V (km./h.) $= c \sqrt{R}$ (m.), in which c varies between 3.6 and 4. Curve 1 figure 1 is that with $c = 4$. The French National Railways go a little further and use curve 2 for the $2'D_0 2'$ locomotives (1 and 2).

Increasing the speed through curves has repercussions on the strength of the track and on the axles, wheels and the springs of the vehicles, on their behaviour whilst in motion and finally on the comfort of the passengers therein. The centrifugal force acting on vehicles running through curves increases as the square of the speed. Such an increase in theory can be compensated by a large increase in the superelevation of the outer rails. In practice, this method cannot be used in most instances as it is not suitable for trains running at

slower speeds and which might have to stop on the curve. Consequently, the elevation of speeds on curves always results in a non-compensated increase in the centrifugal force which is additional to the transverse frictional force and has to be carried by the rails.

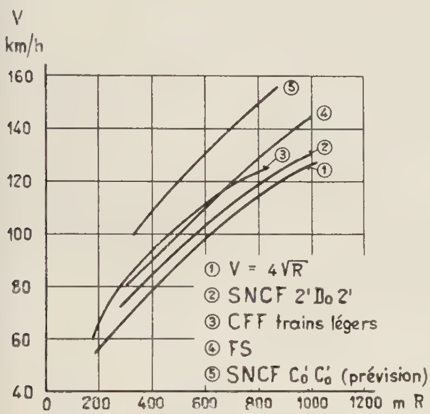


Fig. 1. — Diagram of speeds allowed over curves of various radii.

This increased centrifugal force can be allowed when the total pressure can be distributed over the largest possible number of axles. This means an increase in the number of axles used to guide the vehicle or, better still, a reduction in the load per axle whilst retaining the same number. A satisfactory distribution of the side thrust over all the flanges will be obtained when all the flanges bear against the outer rails with more or less the same guiding force. Of all axle arrangements that using 4 wheeled bogies appears to meet these conditions best. Then too, it is important as regards the resistance of the rails that the pressure of the flanges be distributed over the greatest possible length of rail. In this respect long wheelbase vehicles are the best. In addition to these forces which can be calculated, there are others due to irregularities of the track and to the absence or inadequacy of the transitions, the effect of which is the greater as the speed through the curves is higher. A preliminary condition before speeds can be increased is to have the permanent way always properly lined up and perfectly maintained with transition curves sufficiently long and well set out. A supplementary condition is that the wheels and springing having to stand greater stresses shall be dimensioned to suit and that the vehicles as a whole shall be so constructed that their good riding qualities shall not be affected by the highest speeds run through the curves.

The stability of the vehicles falls off at high speeds through curves but is still more than adequate as is proved by the calculations. It is a good thing after considering the effect of the wheels and springing to reduce the overturning couple by lowering the height of the centre of gravity of the vehicles. The centre of gravity of modern bogie locomotives at high speeds (14-21) is about 1 200 to 1 400 mm. (3′11¼″ to 4′7$^1/_8$″) above the rail, whereas that of the locomotives with frames (1-13) is 1 450 to 1 900 mm. (4′9$^1/_{16}$″ to 6′2$^7/_8$″). If the comfort of the passengers is to be considered then the speed through the curves should not exceed the value V (km./h.) = 5 $\sqrt{R}$ (m.) [1].

As a result of the above consideration the Swiss Federal Railways have adopted the speed curve No. 3, figure 1, for trains of light 4 axle vehicles (low centre of gravity) and with $B_0'B_0'$ locomotives with 14 tonne axle loads (16) on well maintained curves with transition curves. These speeds have been in use regularly since 1946 without any drawbacks whatever.

As a result of further investigations [2]

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(1) *Verkehrstechnische Woche,* November 1933, p. 675 (Leibbrand).

(2) *Revue Polytechnique Suisse,* 1947, No. 45/46 (Pflanz).

these speeds can be permitted with heavier axle loadings provided the curvature is absolutely regular (transition curves) and that the locomotives like the carriages are fitted with equipment such as bolsters, shock absorbers and centring devices. The elasticity of these parts should be such that dynamic effects of the guiding set up by the small inevitable irregularities of the curves be reduced to the minimum.

In the case of the FS locomotives with 17 and 19 t. axle loads (4-14-20) and the $C_0'C_0'$ under construction for the French National Railways with 16.4 t. (21) axle loads the speeds through the curves is to be higher (curve 4 and 5, fig. 1).

Experience will show if they can be maintained without any drawback. The values of the curve 5 are much higher than those of the formula $5\sqrt{R}$. Some discomfort may be experienced by the passengers as it is felt that the limit has been reached in this respect with the speeds of curve 3, which do not exceed the value $4.8\sqrt{R}$.

The power of high speed locomotives.

The highest power P_l that a motor vehicle can develop at the wheel tread is given by the formula :—

$$P_l = G_a.f.v. \quad \text{in which} \quad \begin{cases} G_a. = \text{adhesive weight.} \\ f. = \text{co-efficient of friction between the wheel and the rail.} \\ v. = \text{running speed.} \end{cases}$$

As the co-efficient of friction f diminishes as the speed increases, the power curve is not a straight line but follows the form of curve a of figure 2.

The motor equipment should be designed to attain the limiting power P_l over the largest possible field. The motor vehicles having to work at high speeds ought to have a higher power than those running at lower speeds. The nominal powers at 1 hour rating of the locomotives being considered now are given in column 8 of Table I of the leading characteristics.

Generally, the power developed by an electric locomotive fitted with series motors of the usual types follows the curve b of figure 2. Between the speeds $v = o$ and $v = Vc$ the power the motor equipment can exert exceeds the limiting power P_l; this equipment is not used fully between these speeds. Above the speed Vc, the motor equipment will not enable the vehicle to reach the maximum possible power P_l. The limiting power P_l, ought to be developed up to the maximum speed, that is to say that the motor equipment ought to be designed so that C the point of intersection of curves a and b should be displaced on the ordinate V_{max} to the point C′ of curve b. This would require

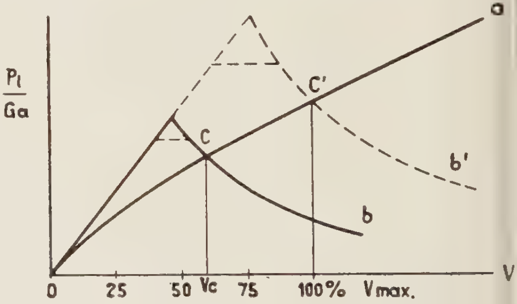

Fig. 2. — Diagram of power developed by an electric locomotive.

too heavy and too costly motor equipment and would make the locomotives too heavy and, from the economic aspect, makes such a solution impracticable. An intermediate solution has to be accepted with which the working is governed by the motor power still available at the maximum speed and the power unusable at lower speeds is within reasonable limits.

Figures 3 and 4 show between what limits the motor power of some of the locomotives considered in this report enables the full limiting power P_l to be

fully developed. The co-efficient of friction used to calculate the curve P_l is selected from KOTHER's (3) formula —

$$f = \frac{9000}{v + 42} + 116 \text{ kgr./t.}$$

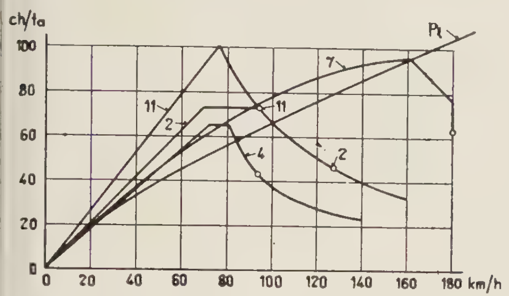

Fig. 3. — Diagram of power of electric locomotives with carrying axles for fast train.

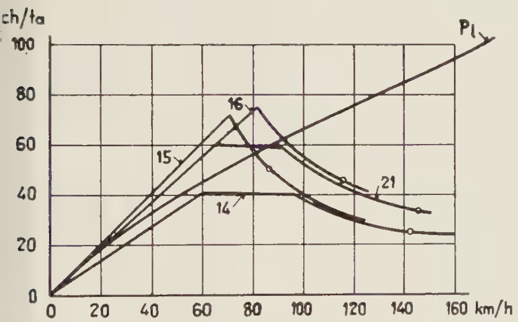

Fig. 4. — Diagram of powers of total adhesion electric locomotives for fast train.

The continuous power per tonne of adhesive weight is marked by a point on each of the curves of figures 3 and 4. The position of this point gives a picture of the heating characteristics of the electrical equipment. Thanks to the progress effected in lightening the mechanical part and the electrical equipment, locomotives with their whole weight used for adhesion have been produced of sufficient power to attain the highest speeds. Figure 4 shows that it has not yet been possible in the case of total adhesion locomotives to get the additional power, as in the case of locomotives with carrying axles (fig. 3) power however rarely used in service (10 and 11).

The ratio between the weight of the power of the locomotives dealt with in the report is interesting. Figure 5 gives the values of the weight per horsepower continuous rating as a function of this power for all the vehicles 1-21 of Table I. The full line connects the points of the figure relating to direct current locomotives : the dotted line relates to alternating current vehicles. The wide variation between these values should be noted between 35 and 20 kgr./H.P. (14, 10 and 11). Generally, the specific weight is higher at lower speeds as would be expected. The weight of the alternating current locomotives is lower than that of direct current locomotives.

Columns 4 and 5 of Table II shew the distribution of weight between the mechanical and electrical parts.

The weight of the electrical part as a percentage of the total weight is as follows :—

(*a*) locomotive with carrying axles :

30-40 % (direct current vehicles) ;

43-48 % (alternating current vehicles) ;

(*b*) total adhesion locomotives :

39-49 % (direct current locomotives) ;

41-49 % (alternating current locomotives).

In (*b*) the mean percentage is higher than in (*a*) through suppressing the carrying axles.

The weight per horse-power of the electrical part (column 7 of Table II) is :—

8.2-17.4 kgr./H.P. (direct current vehicles) ;

9.2-15.8 kgr./H.P. (alternating current vehicles).

(3) *Elektrische Bahnen*, 1940, p. 219 (KOTHER).

TABLE II.

POWER AND WEIGHT OF ELECTRIC LOCOMOTIVES.

Order No.	Power continuous rating.	Total weight.	Weight (on a percentage of the total weight) of		Total weight per H.P.	Weight of the electrical equipment per horse-power.	Type of current
			the mechanical part	electrical			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	H.P.	tonnes	%	%	kgr./H.P.	kgr./H.P.	
1	3520	131.8	64	36	37.5	13.5	=
2	3880	130	66	34	33.5	11.4	=
3	3850	130.5	63	37	33.9	12.5	=
4	3260	134	60	40	41.2	16.6	=
5	2730	92	57	43	33.7	14.6	~
6	3850	108.5	54	46	28.2	12.8	~
7	5060	113	52	48	22.4	10.7	~
8	4720	110.7	52	48	23.4	11.3	~
9	4500	111.4	56	44	24.8	10.8	~
10	5230	105	53	47	20.1	9.4	~
11	5230	105	54	46	20.1	9.2	~
12	3100	102.2	52	48	33.0	15.8	~
13	3600	100	70	30	27.8	8.2	=
14	1920	72	61	39	37.5	14.6	=
15	3800	80	55	45	21.0	9.5	~
16	2280	56	59	41	24.6	10.1	~
17	2240	80	51	49	35.7	17.4	=
18	2340	81	51	49	34.6	17.0	=
19	2900	85	48	52	29.3	14.5	~ (50)
20	2880	101	56	44	35.1	15.3	=
21	3300	98	57	43	29.7	12.6	=

There is, therefore, no marked difference between the direct and alternating current vehicles. However, the lightest weight 8.2 kgr./H.P. (13) and the heaviest weight 17.4 kgr./H.P. (17) are found with direct current locomotives.

The power formula P_t quoted above shows the importance of the adhesive weight as a factor directly affecting the power of a motor vehicle. It determines in conjunction with the permissible axle load, the number of driving axles and as a result and to a large extent the type of locomotive. The adhesive weight of the locomotives considered in this report vary from 56-101 tonnes (16-20). The most powerful vehicle (10/11) is not the one with the greatest adhesive weight. The motor axle loading varies between 14 and 20.5 tonnes (16-8) and the carrying axle loading between 11.5 and 16.5 (3-12). The value of 14 tonnes per motor axle appears rather low : it has been selected in order that the speed through the curve could be increased. As regards the weight on the carrying axles, there is no free choice : it depends upon the difference between the total weight and the adhesive weight required or permissible in the case of the vehicles under consideration.

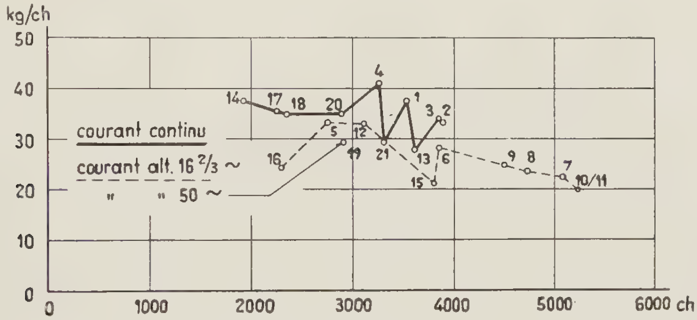

Fig. 5. — Diagram of weight per unit of continuous power rating of high speed electric locomotives.
Courant continu = Direct current. — Courant alt. = Alternating current.

CHAPTER II.

Types adopted for high speed electric locomotives.

The types of electric locomotive adopted for high speed trains in principle do not differ from those used for slower speeds. Most of the high speed electric locomotives in service at the present time are fitted with a main frame carried on the driving wheels. This arrangement, derived from the steam locomotive, has been accepted for a long time as the only possible for high speed work. It requires a guiding bogie or at least a carrying axle at each end to give the guiding needed for good running and for avoiding stresses damaging to the track. Then, too, when the first high speed electric locomotives were built it was not possible to build vehicles powerful enough within such a weight that carrying axles could be suppressed. Vehicles No. 1-4, Table I, for example, weigh 130 - 140 tonnes. The permissible load on the driving axles being 75-80 tonnes, 50-59 tonnes had to be carried on the carrying axles. What was needed was 4 carrying axles in 2 guiding bogies with 11.5-15 tonnes per axle. The whole of the present stock of high speed electric locomotives

of the SNCF is of this type with two carrying bogies (1-3) illustrated in figure 6. The E 428 of the FS (4) is of the same type but has an articulated frame in two parts, which enables the engine to run through curves of 100 m. (328′1″) radius (fig. 7). The weight on the carrying bogies is dead weight which should be reduced as much as possible. By lightening the construction and by increasing the weight on the carrying axles to 13-16.5 tonnes made it possible subsequently to limit the number of carrying axles to two, one at each end of the vehicles (fig. 8). The locomotives with two carrying axles (6-13) weigh 100-113 tonnes only, representing a reduction in weight per horse power of 18-32 % as compared with the bogie locomotives. One of the locomotives of this group (12) is fitted with carrying axles of the Bissel type, which do not appear to be suitable for high speeds. On the others the carrying axle is grouped with the adjoining driving axle to form a bogie. In this way a large number of vehicles (5-9) have been fitted with « Krauss-Helmholtz » bogies, others (10) with « Java » trucks or with SLM (11, 13) bogies. The different construction of these bogies will be examined in more detail in Chapter III.

Fig. 6. — $2'D_0 2'$ Nos. 5546-5550 of the SNCF (1).

The dead weight of these locomotives, however, was 25-30 % of the total weight. Total adhesion vehicles, i.e. with no dead weight, would be of much more interest still. Such locomotives as the $B_0'B_0'$ of the SNCF and the $C_0'C_0'$ of

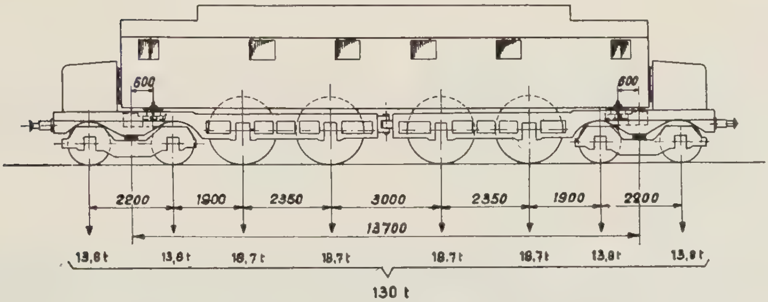

Fig. 7. — Sketch of the E.428 locomotive of the FS (4).

Fig. 8. — $(1A_0)B_0(A_01)$ of the NS (13) with two carrying axles and SLM combined bogies.

the German and Spanish Railways have been in existence some time but were built for speeds under 105 km. (65 miles) an hour. At that time the powers developed were limited by the weight of the locomotive and prevented a high enough tractive effort being developed for high speeds. It was also considered that the locomotives with motor bogies were not suitable for high speeds owing to their small guided length (4).

(4) *Revue Générale des Chemins de Fer*, 1947, p. 38 (Ad.-M. HUG).

Since that time there has been considerable progress. Total adhesion high speed locomotives were even more desirable seeing that the periods of acceleration and braking are more frequent at high speeds owing to speed restrictions in stations and through curves. First of all a high speed locomotive, without carrying axles, seemed to be less dangerous if the driving axle loads were limited to the values so far used for carrying axles, that is to about a maximum of 16 tonnes (see loco. No. 16 - 14 t., No. 21 - 16.4 t.). The Bernese Alps Railway Company (BLS) has gone even further : it was the first to build a $B_0'B_9'$ locomotive of total adhesion with a load of 20 tonnes per axle and a speed of 125 km. an hour (fig. 9). The experiment was a complete success. It demonstrated the practicability of building a $B_0'B_0'$ type when carefully thought out with excellent riding qualities at speeds up to 140 km. an hour. In spite of the 20 t. axle loading the stressing of the track is even less than in the case of a locomotive with carrying axles and with the driving axles in the main frame.

Fig. 9. — Total adhesion $B_0'B_0'$ locomotive of the Bernese Alps railway (15).

It is clear that the power of a total adhesion locomotive cannot be as great as that of one with carrying axles. The difference can be considerable as examples No. 14 (2 160 H.P.) and No. 4 (3 800 H.P.). However, the progress that has been made in lightening the

construction has made it possible to get as much as 1 000 H.P. per axle (15) and, therefore, remarkable tractive efforts at high speeds.

The high speed electric locomotives in service so far usually have 4 driving axles. The power developed, up to 1 400 H.P. per driving axle (7, 8, 10, 11) is ample for the traction requirements. This is no longer the case for total adhesion locomotives, especially when it is felt to be well to limit the axle load to less than 20 tonnes. Under such conditions, it would mean using locomotives with 5 or 6 driving axles (19, 20, 21). The only high speed locomotive with 6 driving axles in use at the present time is the type E 636 of the FS (fig. 10). This engine has three bogies, each with two driving axles. In order to avoid the difficulties caused by the suspension of the body and the distribution of the weight over three bogies and the very considerable lateral displacement of the middle bogie might cause, the body of this locomotive is divided into two halves connected by articulated couplings. In addition total adhesion locomotives with 5 and 6 driving axles are being built for the Hungarian State Railways (19) and the S.N.C.F. (21). The first of these has one two axle and one three axle bogies, whereas the six motors of the second are carried on two six wheeled bogies. The bodies of these locomotives are of the usual construction and are not articulated. These new types deserve the careful consideration of all Railways and their practical results are being awaited with the greatest interest.

Fig. 10. — FS $B_0'B_0'B_0'$ with 3 motor bogies and articulated body (20).

CHAPTER III.

Mechanical parts.

A detailed and complete description of the mechanical part of the locomotives dealt with in this report cannot be given in this chapter. It is interesting, however, to examine some parti-

cular constructions, old or new, that had to be used for the highest speeds or were made use of to assist in reducing the weight of the traction rolling stock.

Main frame.

The frame of high speed electric locomotives with carrying axles are as a rule of the « classic » type with main frame plates, buffer beams and cross stays. The main frames of 24-30 mm. ($^{15}/_{16}''$ to $1^{3}/_{16}''$) thick plate, may be 1 000 mm. ($3'3^{3}/_{8}''$) or more in depth to stand the stress of lifting the complete locomotive. The cross stays and buffer beams in thinner plate or in cast steel are assembled to the main frames by riveting and by bolts (1-5, 10-11, 13) or by welding (6-9, 12).

If the frame is articulated (4), the two halves are coupled together by a spherical pivot at the middle (fig. 7). Side shock absorbers limiting the hunting motion on the straight ([5]) are fitted.

The axles of the main frame have either inside (1, 10, 11, 13) or outside (2-9, 12) bearings. The boxes work in guides which transmit the traction and braking efforts. The play varies between 0.5 and 2 mm. ($^{5}/_{256}''$ and $^{5}/_{64}''$) in the longitudinal plane : in certain cases no play is allowed (12).

The axle spacing, which varies and is relatively great does not exceed a maximum of 7 200 mm. ($23'7\frac{1}{2}''$) (6-9). This requires a lateral play in the case of the middle axles (1-3, 10-13) of as much as 2×26 mm. ($2 \times 1^{1}/_{32}''$). If this play is low, and the rigid wheel base makes it necessary, the middle wheels have thin tyres. Many of the locomotives (5-9) have a side play of 2×15 mm. ($2 \times {}^{19}/_{32}''$) with the middle wheel flanges reduced by 10 mm. ($^{25}/_{64}''$) in thickness.

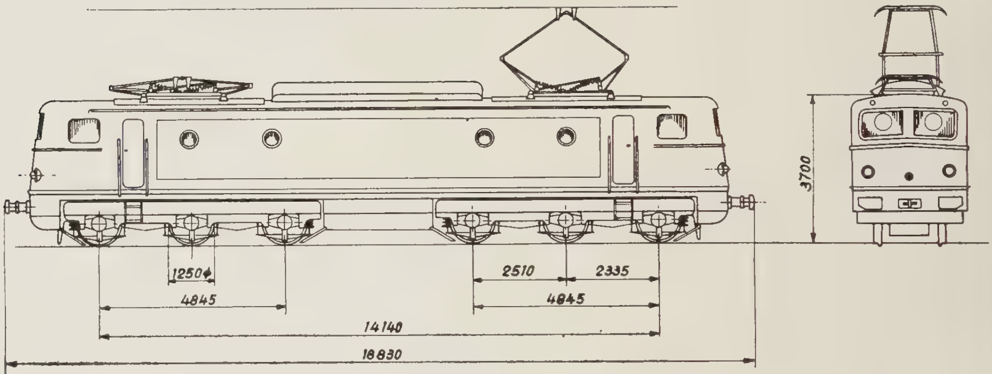

Fig. 11. — Sketch of the $C_0'C_0'$ locomotive under construction for the SNCF (21).

The spring suspension consists of laminated springs placed under or on the axle bogies connected by equalisers.

When the frame is in one piece, the body forms part of it. If articulated (4), the body is carried by the frame through elastic supports and spherical centres.

The reduction in weight of the mechanical part as led to the creation of tubular bodies (14-17, 19-21) as in the case of carriages ([6]). In this case the frame and body form a unit in which all details (base, sides and roof) add to the strength (fig. 12). A frame of this kind, being only a base for the body, differs considerably from the

([5]) *Rivista Tecnica delle Ferrovie Italiane,* 1935, vol. 47, p. 255, and vol. 48, p. 48 (BIANCHI).

([6]) *International Railway Congress,* Lucerne Session 1947. Question II. Report by R. GUIGNARD.

« classic » frame which by itself has to support and transmit all the shocks and tractive efforts and also to withstand lifting and possibly collision. In the most recent engines (15, 16, 17, 21) it consists of, at buffer height, tubular longitudinal members fabricated by welding from 5-6 mm. ($^{13}/_{64}$″-$^{15}/_{64}$″) plate: This new method simplifies and lightens the bogies.

Body.

The body usually is one with the frame. If the body plays no part in the strength, its framing in rolled sections is secured to the frame by rivet-

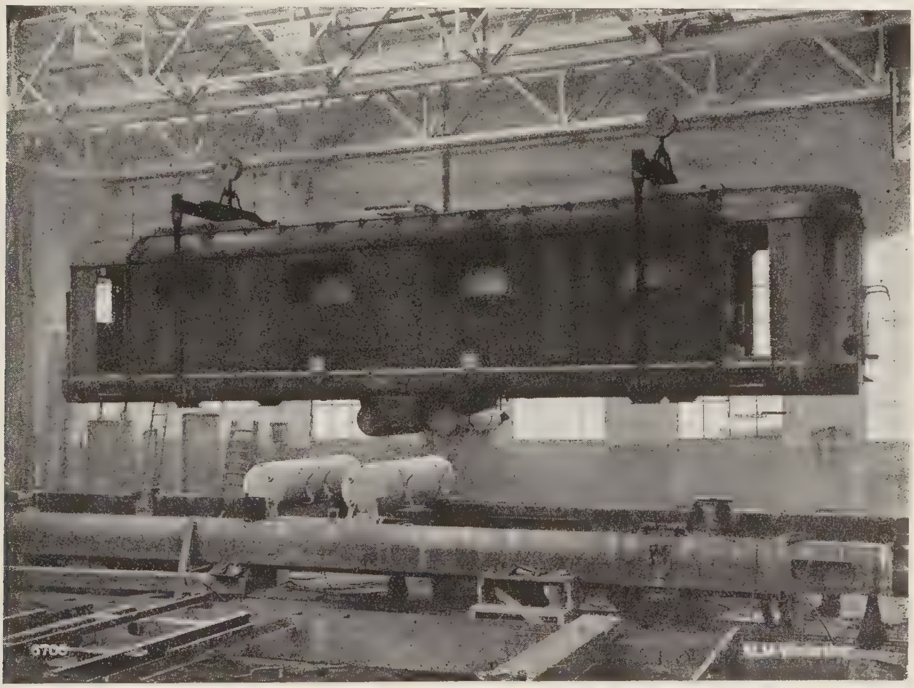

Fig. 12. — Tubular body of the $B_0'B_0'$ of the Swiss Federal Railways with driving cabin made of light metal (16).

the headstocks are boxes and the cross-stays tubular girders (fig. 13). These different parts are also fabricated by welding. This form of construction is only used on bogie locomotives.

In all the above-mentioned types, the buffing and drawgear are carried by the frame, unlike the old construction of bogie locomotives in which these parts were fastened to the bogie headstocks.

ting, bolting or welding. The sides and roof are made of panels of sheet steel or copper bearing (18) steel 2-2.5 mm. ($^{5}/_{64}$″-$^{25}/_{256}$″) thick. They can be taken off and are secured to the framing by rivets or bolts. These removable panels sometimes are made of aluminium for ligthness (6-9).

The bodies known as tubular (14-17, 19-21) are in sheet steel or copper bear-

ing steel (17), 2-4 mm. ($^5/_{64}''$-$^5/_{32}''$) thick. The different sections, floor, sides and roof, are assembled by welding or rivetting. The sides are fixed but part of the roof is removable to enable the equipment to be taken down. In some instances the tubular longitudinal girders are used as compressed air reservoirs (4, 14, 20). To reduce weight the removable section of the roof and the portion of the body outside the lifting points (cabs) may be in light alloy (10, 11, 16, fig. 12).

To reduce wind resistance when running and for appearance sake, the body is more or less streamlined. In some instances all that is done is to round off the angles of the cab ends (10-12, 15-19, fig. 9). The drivers' cabs are given either an angle front (4, 14, 20, fig. 10) or sloped back with the angles rounded off and a bonnet at the extreme end (1-3, 6-9, 13, figs. 6 and 8) and in certain cases side shields (21, fig. 11). As the locomotive is reversible and to facilitate access to the coupling, running gear, bearings, brake blocks, springs, etc., a more efficient streamlined shape cannot be used. This, however, is less important than with steam locomotives, the power of which is more limited.

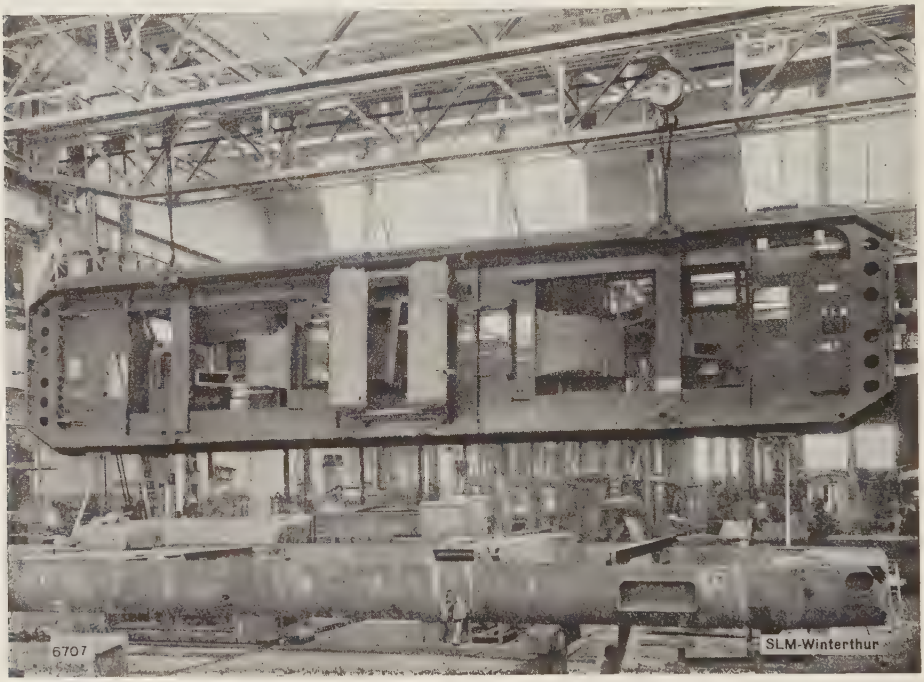

Fig. 13. — Frame forming the floor of the body fig. 12.

The interior of the locomotive is arranged as follows : a driving cab at each end, an engine compartment in the middle, a central corridor or like a Z (15), or one or two side corridors. As a special case, that of locomotives with distant control which can be formed in the train, a second side corridor is provided completely isolated from the

engine compartment (16). Most locomotives for multiple operation or distant control (10, 11, 14, 16, 19) have an end door with gangway and in one case (16) gangway bellows.

Carrying bogies.

The bogie side frames or sole bars are made of 25-28 mm. (1″-1$^{1}/_{32}$″) thick plate riveted to the stretchers and stays in plate or cast steel. The axles have carried by the bogie on a central pivot and bolster with 150-163 mm. (5$^{29}/_{32}$″-6$^{7}/_{16}$″) side movement (1-3) or on special side bearings (4). In the latter case the central pivot does nothing except to transmit the tractive and brake efforts and to restore the bogie to its normal position when running. The pivot is either on the transverse centre line of the bogie (4) or off centre towards the inner axle (1-3) in order to take some of the load off the outer carrying axles.

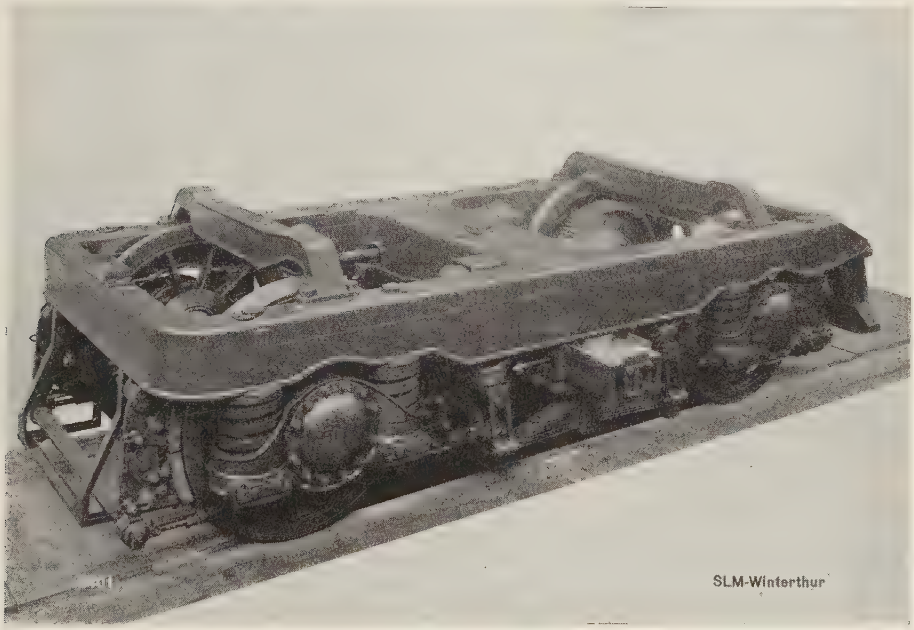

Fig. 14. — Motor bogie of the BLS Co.'s $B_0'B_0'$ locomotive (15).

either inside (1, 2, 3) or outside (4) bearings. The boxes work in guides. The wheel base of carrying bogies varies between 2 200 mm. (7′2$^{5}/_{8}$″) and 2 400 mm. (7′10½″) (1-3).

The springing of the bogies consists of spring hangers, coiled springs and laminated springs on the axle boxes. The main frame of the locomotive is

In order that the riding be satisfactory at high speeds and with no hunting, the centring springs are given a substantial initial load. The centring devices with cranked levers, springs and rollers, act in such a way as to limit the centring forces to safe values (5).

In the type of construction adopted on the SNCF $2'D_02'$ (1-3) locomotives a

lateral force and a restoring movement act on the pivot at the same time (7).

Motor bogies.

The construction of the motor bogies of high speed locomotives cannot be the same as that used previously for vehicles running at lower speeds. The old designs did not give good riding at high speeds and damaged the track too much, both on curves and on the straight. When designing a new bogie the greater loads to which all parts of a high speed vehicle are subjected have to be taken into account. The question is to make the bogie stronger without increasing the weight. The frames of such modern motor bogies are no longer built up of rolled sections but consist of tubular frames, headstocks and cross-stays fabricated by welding 8-12 mm. ($^{5}/_{16}$"-$^{15}/_{32}$") thick plate (fig. 14). Particular attention is given to the lines of welding which ought not to be at positions subjected to high stresses. On the FS locomotives (14, 20) some of the cross-stays of the motor bogie are formed of tubes used partly as air reservoirs.

The axles of all the motor bogies considered in this report have outside journals. Two systems of springing of the bogie frames are to be noted. The first (14, 20, 21) hardly differs from old designs and consisted of laminated springs carried on the axle boxes with adjustable spring hangers and in one case (21) with equalising levers and supplementary coiled springs (figs. 15 and 16). In the second method (15-18) the bogie frame rests on 8 coiled springs carried in two spring brackets, one on each side of the axle box (fig. 14).

The axle boxes are guided in various ways :—

a) by the axle box horns and guides (14, 17, 19, 20, fig. 15);

b) by links carried by silent blocks (8) (21, fig. 17). Under the action of ver-

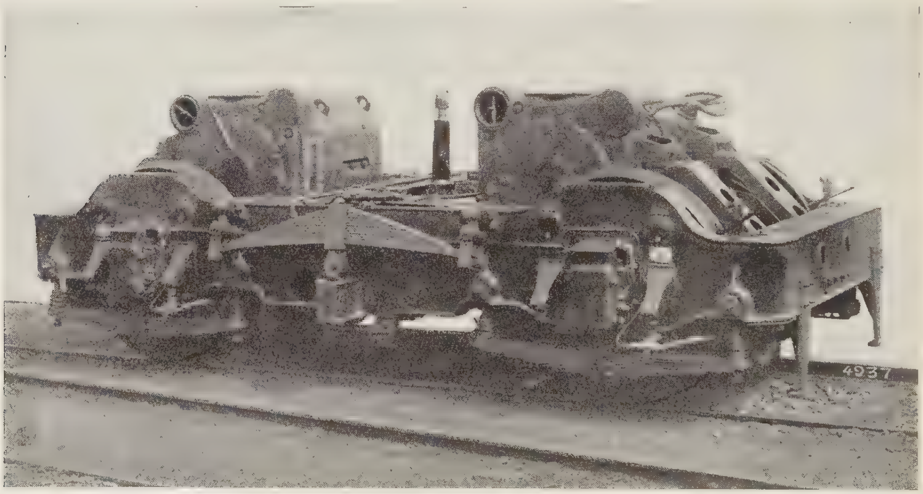

Fig. 15. — Motor bogie of the FS $B_0'B_0'$ E 424 and the $B_0'B_0'B_0'$ E 636 (outer bogie) (14, 20).

(7) PARODI : *Partial electrification of the P.O. Railway*, 1928, p. 207.

(8) *Revue Générale des Chemins de Fer*, 1947, p. 113 (TROLLUX).

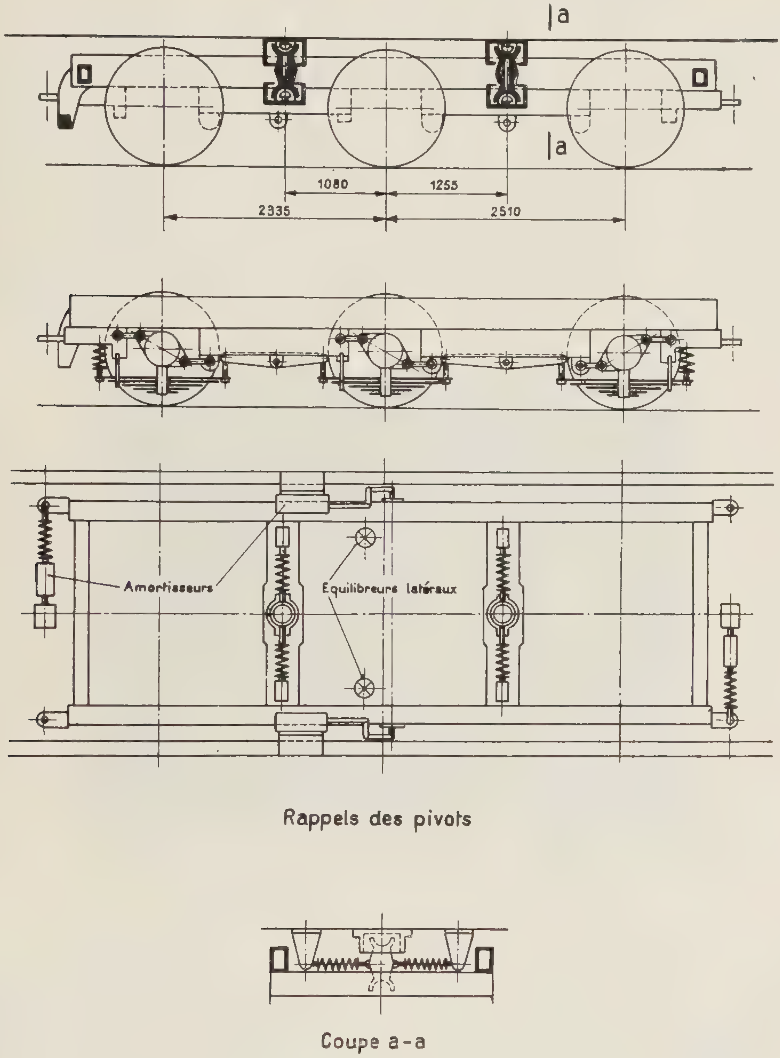

Fig. 16. — Diagram showing the principles of the $C_0'C_0'$ locomotive bogie under construction for the SNCF (21).

Amortisseurs = Shock absorbers. — Equilibreurs latéraux = Lateral equalisers. Rappels des pivots = Pivot back-spacers. — Coupe = Section.

tical and lateral loads transmitted to the axle box the rubber blocks (silent blocks) undergo torsion or compression thereby setting up a recentring force : the vertical movements of the axle cause a very slight rotation of the axle box which is in no way objectionable;

c) by cylindrical plungers which work inside the suspension springs, the construction of the SLM (9) arrangement being shown in fig. 18 (15, 16, 18).

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(9) *Revue Technique Suisse*, 1947, No. 38/39, pp. 629-631 (Bodmer, Borgeaud, Meyer).

In this system the rubber silent blocks enable play to be suppressed, transfer the guiding forces and damp the lateral shocks. To damp the movements of the coiled springs, friction brakes are fitted under the side supports of each axle box.

The motive or braking forces are transmitted either by the axle guides or by the guiding links of the axle box or by the cylindrical plungers and the silent blocks already referred to.

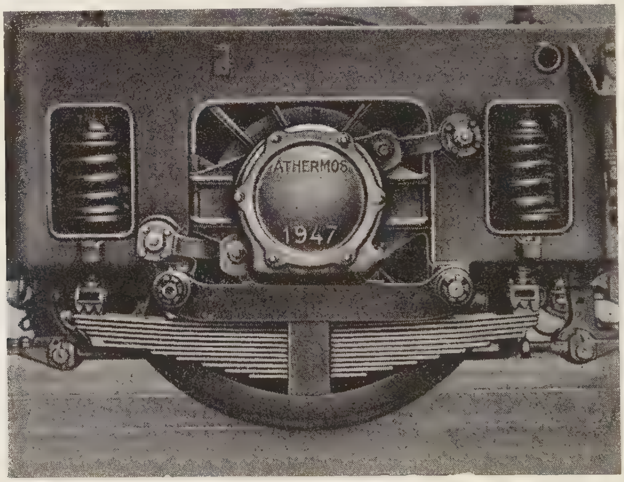


Fig. 17. — Athermos axlebox guided by links carried on silentblocks.

To get satisfactory riding at high speeds and to avoid the drawbacks of lowering the centre of gravity, an increasing number of locomotives are fitted with double suspension. In this arrangement the body is not carried directly by the bogie frame but through elastic supports, such as springs. Figure 19 shows the springing used on certain locomotives (15, 16, 18) ([10]). In this system the body is held at each end by two side brackets bolted to a cross member placed under the bogie frame. This cross member rests near its end on two laminated springs suspended from the bogie frame by inclined links. The two springs are connected by a girder held laterally by an auxiliary pivot fastened to the body bolster. The main pivot is part of the bogie frame and engages with the body bolster by a slide with a side play of 2 × 30 mm. (2 × $1^3/_{16}''$). The pivot consequently can only transmit longitudinal efforts between the bogie and the body, and, in particular, the traction and brake forces. The vertical load due to the body is transmitted to the wheels through the bolster and the suspension springs, remaining more or less in the same vertical plane, whereas the laminated springs and their suspension links and the connecting girder deal with the transmission of the side forces.

Side movements of the body relative to the bogie are restored by gravity by the inclined links of the laminated springs. The friction surfaces of the side bearings of the body do all that is

([10]) *Revue Polytechnique Suisse*, 1946, vol. 127, p. 218 (GERBER).

needed to prevent hunting. Some of the locomotives (15, 16) are fitted with an anti-hunting centring device mounted inside the body bolster. The centring force only acts at very small angles of deviation of the bogie; it is suppressed at large deviations to avoid its harmful effect on curves.

The Italian locomotives (14) have bogies like the last (fig. 15). In this arrangement, the centre pivot is fastened to the body and is carried on the bolster between the body and the bogie are damped out by hydraulic gear (11).

Three axle bogies.

In the Alsthom system (21) fig. 16 (12) two pivots in the form of a crutch allow further rotation and a certain lateral movement of the bogie relatively to the body. One of the crutches is held in the longitudinal direction and so transmits the tractive and braking forces. The two are connected to the body by

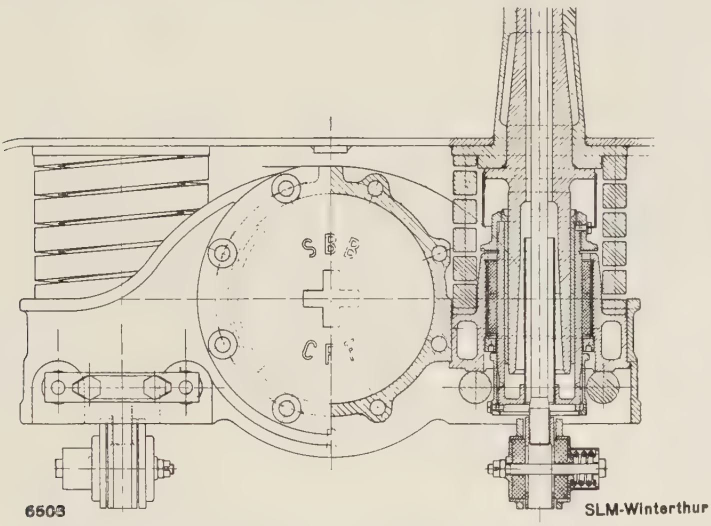


Fig. 18. — SLM axlebox of the Swiss $B_0'B_0'$ locomotive (15, 16) with suspension springs and guiding arrangement.

by a spherical bearing. This body is made to bear on the bolster and the tractive and braking efforts are transmitted through it. These forces are transmitted in turn through 4 links to the bogie. The arrangement is shown in figure 20 : the layout is different on the middle bogie of locomotives with three bogies (11) (20). The bogie bolster is supported from the bogie by two laminated springs and inclined pinned swing links. The movements of rotation links tending to restore them to their vertical position, i.e. to restore the centre line of the bogie to a position parallel with that of the body. Hydraulic shock absorbers can be fitted in addition to these swing links. The two links make the body and the bogie one in the vertical plane so that the bogie cannot tilt : the useful adhesion of the bogie is improved in this way.

In the Ganz-Rónai (19) system there is no pivot. The body rests on four

(11) *Rivista Tecnica delle Ferrovie Italiane*, 1941, p. 149 (D'ARBELA).

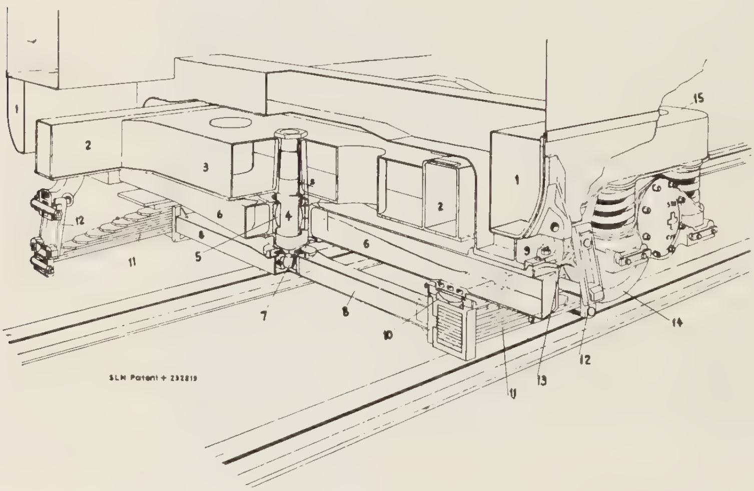
(12) *Chemins de fer*, 1948, No. 149, p. 27 (Daniel CAIRE).

fixed bearings on the solebars of each bogie. Two of these bearings prevent hunting by friction. The other two are fitted with Rónai centre-castings which guide the bogie and transmit the traction and braking efforts between the bogie and the body.

Generally speaking the point of transmission of the tractive effort between the bogies and the body is on a plane at the height of the centre line of the axles (19 excepted). This layout has the benefit of reducing appreciably the fastened to the two soles (fig. 14). Elastic elements, such as rubber pads, are sometimes interposed between the motors and the bogie frames.

The wheelbase of the bogies considered varies between the limits of 2 500 and 3 600 mm. ($8'2\frac{7}{16}''$ and $11'9\frac{3}{4}''$) for four wheeled bogies and between 3 500 and 4 845 mm. ($11'5\frac{13}{16}''$ and $15'10\frac{49}{64}''$) for six wheeled bogies (19 resp. 21).

The bogies of some locomotives are coupled through a flexible transverse coupling (15, 16). This coupling does



1 : Body beam.
2 : Bogie frame.
3 : Median cross-member of bogie.
4 : Bogie pivot.
5 : Pivot slide.
6 : Swing bolster.
7 : Spherical pivot for lateral drive of the springs.
8 : Tail - outrigger of the springs.
9 : Body bearing piece.
10 : Lateral bearing deviec with lubricating oil bath.
11 : Body springs.
12 : Pendular stirrup-piece.
13 : Longitudinal connecting-rod of the body springs.
14 : Driving wheel.
15 : End sill of the bogie frame.
S : Lateral play of the suspension of the body.

Fig. 19. — Diagrammatic section of the SLM motor bogie (15, 16, 18).

unloading of the leading axles in the direction of running when starting and so increases the useful adhesion. There are arrangements in use for equalising the axle loadings on some locomotives (15, 16, 18). With these devices pneumatic pressure can be exerted on the leading headstock of the bogie.

The fully springborne traction motors are bolted to the bogie frame, on the one hand to a middle cross-bearer and, on the other, either to arms bearing on a headstock (fig. 15) on to the second middle cross-stay of the three axled bogies, or to a girder forming a stirrup not transmit the tractive efforts but reduces the guiding forces and the angle of attack of the leading axle of the bogies. The result is a notable reduction in tyre wear [13].

Combined bogie.

Combined bogies consist of having in one frame the carrying axle guiding the locomotive and the adjacent motor axle. The object is to improve the riding of the motor vehicles at high speeds,

[13] *International Railway Congress Bulletin*, August 1948, p. 527.

reduce the forces between the wheels and the rails on curves, and ensure perfect guiding on the straight.

Several of the locomotives mentioned in the report (5 to 9) have at each end a combined bogie of the *Krauss-Helmholtz type* (fig. 21) (14).

This bogie has a secondary frame made of 25 mm. ($^{63}/_{64}''$) thick plate and rolled sections welded together. This frame is carried at one end on the axle boxes of the carrying axle with its inside journals through laminated springs and coiled springs coupled by spindles; at the other end it is carried off the main frame of the locomotive through an articulated pin. A pivot, fastened to the main frame, engages with a slide fitted to the secondary frame with a lateral movement of 2 × 50 to 65 mm. (2 × $1^{31}/_{32}''$ to $2^{9}/_{16}''$). The driving axle with outside journals is held in place longitudinally by axle guards bolted to the main frame. It can move laterally 2 × 15 mm. (2 × $^{19}/_{32}''$) it is guided by the secondary frame through a V shaped member which controls the axles at the ends of the journals. This rather complicated construction is different from the original Krauss-Helmholtz bogie used on other electric and steam locomotives; it has its origin in the system of driving axles with a quill drive. The body rests on an unsprung centre-casing placed above the carrying axle which is able to move sideways 2 × 75 to 100 mm. (2 × $2^{61}/_{64}''$ to $3^{15}/_{16}''$) relatively to the axis of the secondary frame. The centre-casing and the pivot slide are returned to the mid position by a laminated spring, the initial load on which can be varied by a pneumatic device. This arrangement is automatically controlled by the reversing gear so that the centering force does not exceed 2 300 kgr. (5 070 lbs.) on the leading bogie and 4 900 kgr. (10 800 lbs.) on the trailing one.

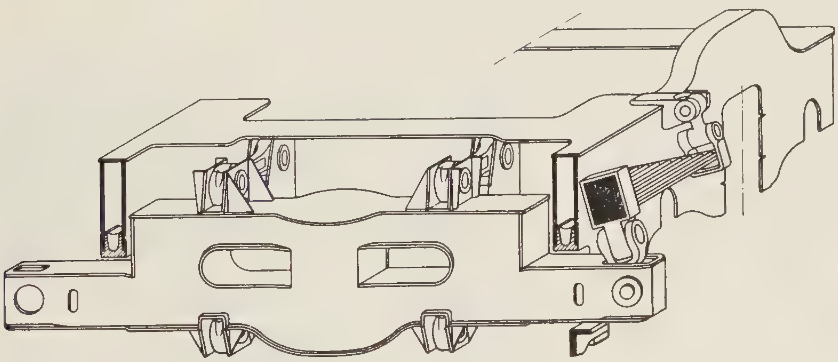


Fig. 20. — Diagram of the springing of the bogie bolster of the bogie shown in fig. 15.

The Krauss-Helmholtz bogie allows a limited lateral movement of the driving axle only; in consequence the angle of the axle on curves is large and there is heavy wear of the tyres. To overcome this difficulty some other locomotives (10) are fitted with the « Java » bogie (fig. 22) (15).

In this design, the driving axle is

(14) *Elektrische Bahnen*, 1933, p. 153, 1936, p. 130, and 1939, p. 92 (KLEINOW).

(15) *Bulletin Technique SLM*, October 1944, p. 21.

included in the secondary frame, and consequently can rotate to some extent as well as move sideways 2 × 20 mm. (2 × 25/32″) relatively to the main frame. The bogie frame is built up of plate and castings welded together; it rests on the carrying axle with inside journals through laminated springs carried on the axle boxes and coiled springs mounted in series. It bears directly on the driving axle with inside journals likewise. The pivot does the guiding. It is one with the main frame and only transmits the driving and retarding forces; it has 2 × 55 mm. (2 × 2 11/64″) play. The main frame is carried by the bogie at the middle of the driving axle by a swivel crutch and two laminated springs. It is in addition supported off the axle box through spring hangers and plate springs under them. The crutch can move 2 × 120 mm. (2 × 4 23/32″) sideways. The pivot, alone, has a centering device of levers and a laminated spring acting in the lateral direction without hindering the rotation of the bogie.

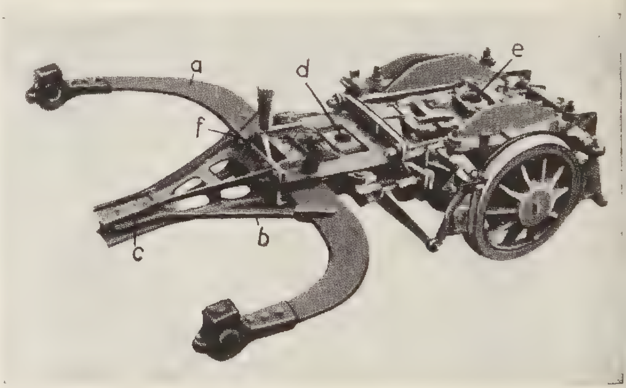


Fig. 21. — Combined Krauss-Helmholtz-AEG bogie of the $1'D_01'$ E 18 of the German railways (6).

a = stirrup or swing link.
b & *c* = guiding fork.
d = pivot slide.
e = pivot centre plate of the main frame.
f = spring hanger bolt of the secondary frame.

The most recent locomotives with carrying axles (11, 13) built by the « Société Suisse pour la Construction de Locomotives (SLM) » are fitted with the *combination SLM bogie* (figs. 23, 24), derived from the « Java » truck (15).

The SLM improvements are to the frame, springing and the centering device. The bogie frame, a steel casting, is fully sprung off both the carrying and driving axle boxes by springs and hangers. The main frame is not carried any longer by the driving axle boxes as on the « Java » truck but rests on two side bearings on the two sides of the pivot; these bearings are elastic on the latest locomotives. With this method of construction equalising levers cannot be used between the bogies and the main frame to equalise the loads on the driving axles. The result is that the driving axle of the rear bogie in the direction of running is more or less relieved of its load under the tractive efforts at the drawbar. To overcome this, these bogies are fitted with an electro-pneumatic compensating device controlled by the reverser and operated, as desired, by the driver. The pivot of this type of bogie behaves like that of the « Java » truck : its side movement is 2 × 50 to 55 mm. (2 × 1 31/32″ to 2 11/64″). The bogie is fitted with two centring devices : one is arranged above the carrying axle, the other at the end of the bogie adjacent to the driving axle. These devices are secured to the main frame and connected to the bogie by the links A shown in figure 23 : they pro-

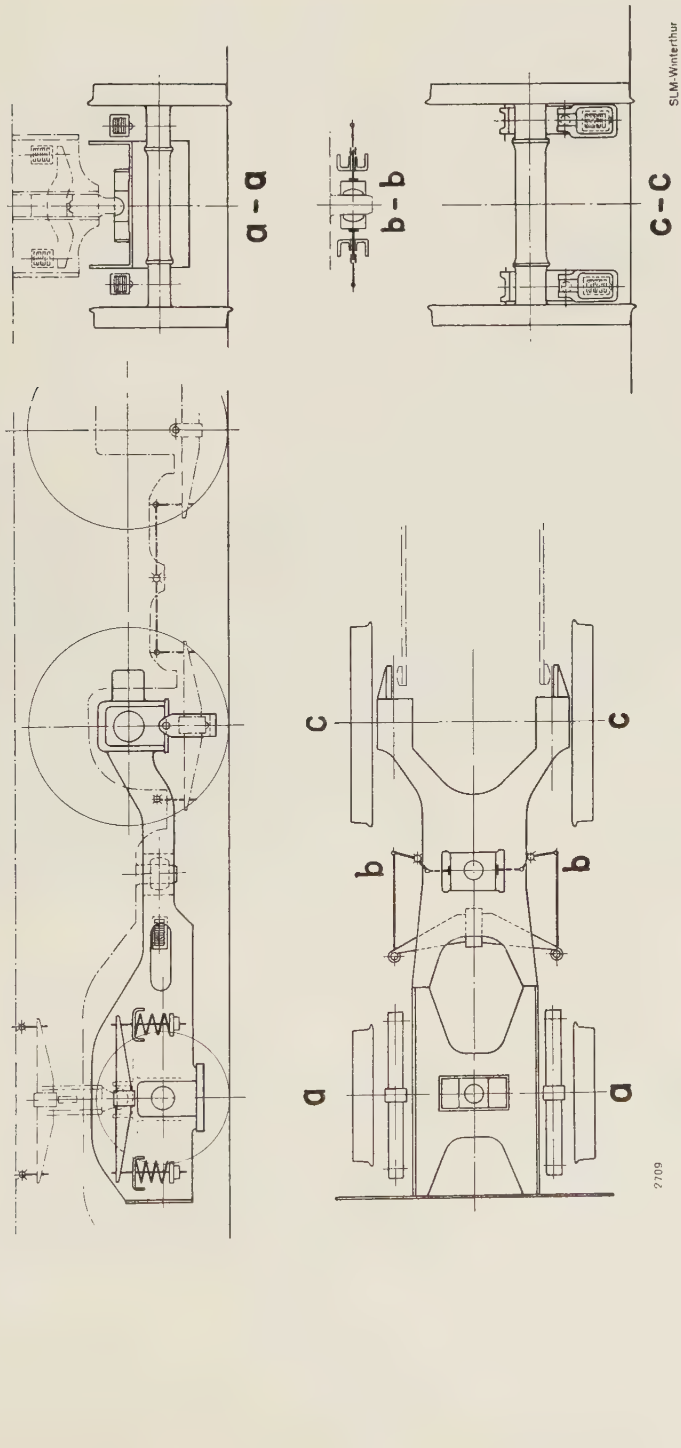


Fig. 22. — Diagram of the « Java » type combined bogie of the CFF $1'D_01'$ locomotive (10).

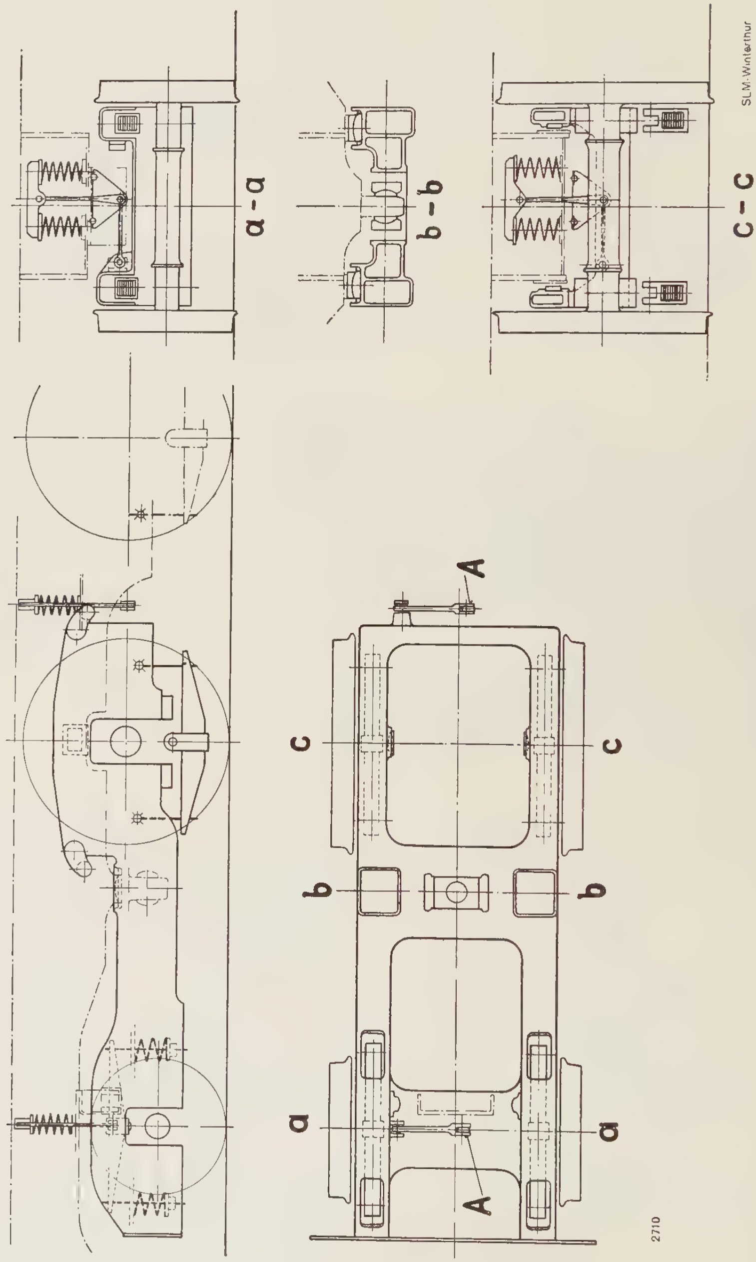


Fig. 23. — Diagram of the SLM combined bogie.

duce large centring forces on straight track, whereas on curves, that is to say when the bogie turns a large amount, these forces are substantially reduced. This double self centring arrangement ensures that the locomotive is more rigidly held on straight track, whilst avoiding undue reaction on the track when running through curves : in this way too the wear of the flanges is reduced. Possible hunting is effectively damped out by the friction of the two side bearings.

The wheelbase of the combined bogies considered in the report varies from 2 500-2 800 mm. (8′2$^{7}/_{16}$″-9′2¼″) (10, 11 resp. 5 to 9) the diameter of the driving wheels varies from 1 350-1 600 mm. (4′5$^{1}/_{8}$″-5′3″) and that of the carrying wheels from 950-1 100 mm. (3′1$^{3}/_{8}$″-3′7$^{5}/_{16}$″).

Running gear.

The driving axles are usually made of carbon steel and occasionally of chrome-nickel steel (12). The use of this latter material is being given up more and more for axles, as, although it has greater tensile strength, its resilience is lower and it is less resistant to shock. The diameter of the body of the axles varies between 150 mm. (5$^{29}/_{32}$″) the minimum (16) and 240 mm. (9$^{7}/_{16}$″) the maximum (2). The axle is frequently hollow for lightness, the diameter of the hole through it being 70-80 mm. (2¾″-3$^{5}/_{32}$″) (1, 2, 4, 10, 11, 14, 20, 21).

The *carrying axles* in all cases are made of carbon steel. Their diameter varies from 150 mm. (10, 11) to 185 mm. (7$^{19}/_{64}$″) (1 and 3) on a maximum. In many cases hollow axles are used (1 to 4).

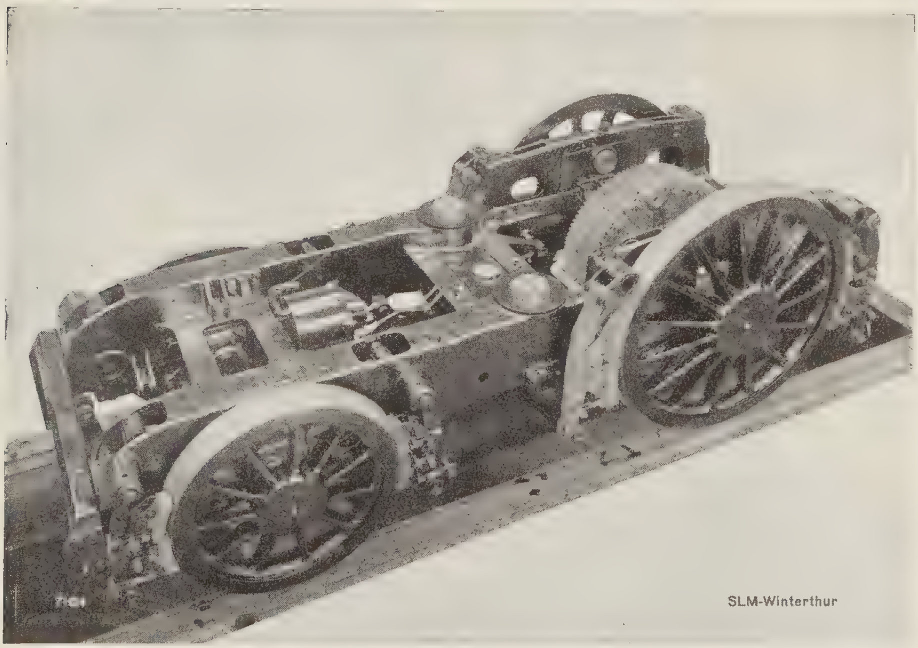


Fig. 24. — SLM combined bogie of the NS $(1A_0)B_0(A_01)$ locomotive (13).

The *wheels* are cast steel centres shrunk on the axles and fitted with tyres. The one-piece wheel is not used on any of the locomotives considered.

The tyres are carbon steel of 70-90 kgr./mm² (44.44 t. to 57.14 tons per sq. inch) tensile, except for an experimental locomotive, which is running on 100 kgr./mm² (63.49 tons per sq. inch.) tyres (8). The dimensions are usual with the exception of the SNCF $C_0'C_0'$ locomotives (21), which will have 90 mm. ($3^{36}/_{64}''$) thick tyres instead of the usual 75 mm. ($2^{61}/_{64}''$).

The diameter of the driving wheels varies from 1 036 (19) to 1 880 mm. (4) ($3'4^{51}/_{64}''$ to $6'2''$): that of the carrying wheels from 950 (10,11) to 1 100 mm. (4, 13) ($3'1^{3}/_{8}''$ to $3'7^{5}/_{16}''$). The maximum number of revolutions per minute at the maximum speed is 640 for the driving wheels (19) and 950 for the carrying wheels (7, 8).

A large number of the locomotives examined is still fitted with *axle boxes* of the old design with flat axle box guides and pad lubrication (1, 2, 4, 10, 11, 13). Higher speeds, longer non-stop runs and increased axle loads all necessitate a system of lubrication with a greater supply of oil and better axle box tightness to reduce the losses of oil and improvements to reduce maintenance work. The first stage towards improving the lubrication consists in adding one or several lubrication pumps driven by the axles and circulating continuously a certain quantity of oil through the boxes (10, 11, 13).

It would appear moreover that axle boxes with lubricating pads are being more and more given up in the case of high speed locomotives and that oiling by capillary attraction is giving place to continuous lubrication by mechanical pumps. Various applications of this principle are in use under the names of Isothermos, Athermos, Peyinghaus and Friedmann. In these the oil is circulated by a paddle secured to the axle or by a disc attached to the journal end. A good number of locomotives are fitted with Isothermos boxes (figs. 16 and 17) both for motor axles with outside journals (3, 6 to 9, 21) and for carrying axles with inside journals (5 to 9). In some instances, there is a proposal to convert axle boxes with lubricator pads into Isothermos boxes. Inside boxes of altered motor axles are under trial (1) : designs are in hand for altering the inside boxes of motor and carrying axles of another series of locomotives (10/11). The mechanically lubricated axle boxes are giving admirable results : it has been found possible to run 200 000 km. (125 000 miles) without adding any oil.

Roller bearing axle boxes in use on carriages and wagons for more than twenty years are newer on locomotives. In particular they are to be found on the outside journals (12) of total adhesion locomotives (14-20). Some carrying axles with inside journals (3, 12 in test on 1) and motor axles with outside journals of a group of $1'D_01'$ (12) locomotives are also being fitted with them. The preference in these bearings is for the single or double row spherical roller type with the rollers lubricated by grease or in a few cases by oil (3). The results too are excellent, the distance between oiling being as great as 400 000 km. (250 000 miles). The use of such bearings means very accurate fitting and good quality grease. As roller bearing boxes do not stand the passage of electric currents, they have to be shunted by means of brushes rubbing on rings on the wheel centres.

CHAPTER IV.

The method of driving the axles.

General.

In the case of the classic type of steam locomotive, it is logical to transmit the

driving force to the wheels by means of rods. Contrariwise on electric locotives with the armature having a rotary motion, it is natural to endeavour to transmit the motion direct to the wheels without intermediary rods. It is not, therefore, surprising that none of the high speed locomotives considered in the report has rod drive. Nevertheless, three motors drive, therefore, two adjacent axles [16]. On all the other locomotives considered the motor axles are *individually driven.*

The individual drive of an axle by a single motor is the simplest and cheapest solution. With this system and when the motors are carried on the main frame it is possible to develop

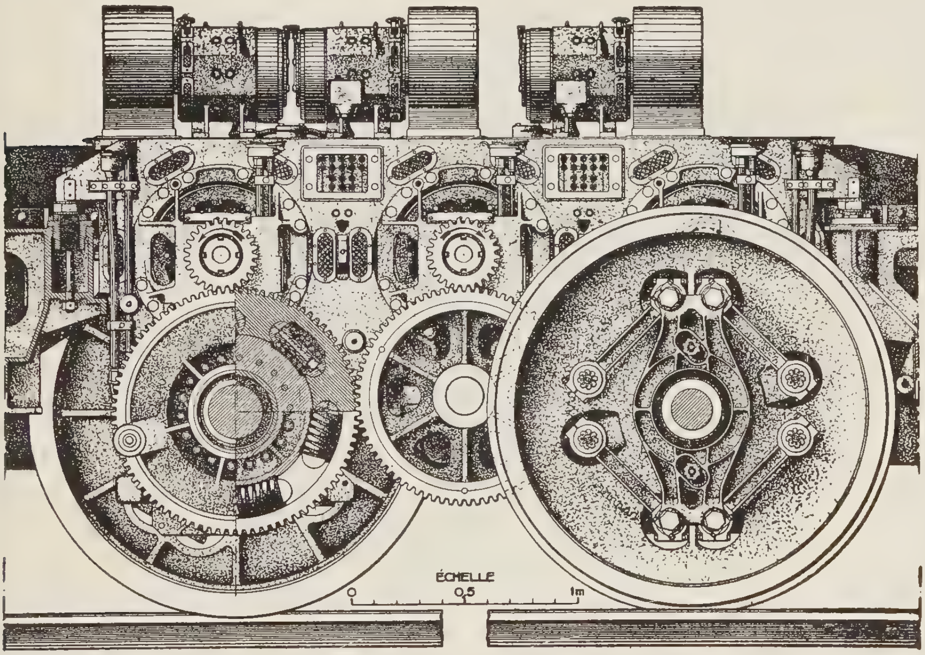


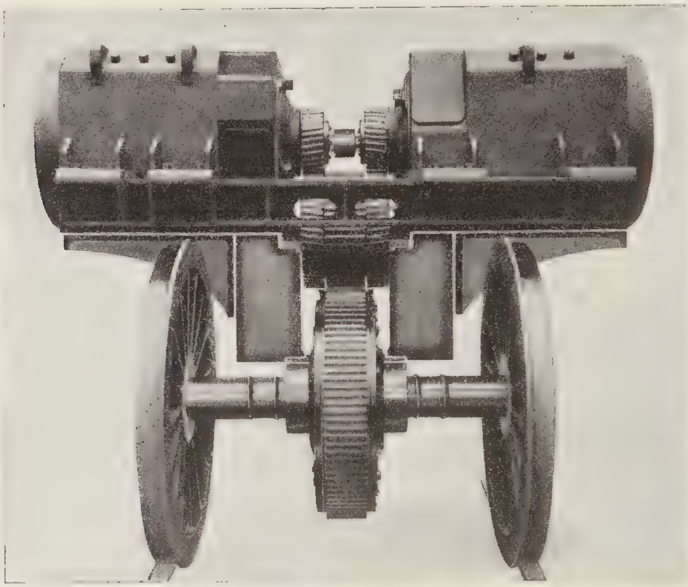
Fig. 25. — General arrangement of a pair of axles of the SNCF 2′BB 2′ locomotive (3).

for reasons of adhesion the coupling of the driving axles might well be of interest. As there are many difficulties in the way of coupling the axles almost all high speed electric locomotives are not coupled. Amongst the locomotives we are considering, there is only one type (3) with the two adjacent axles fitted with gear wheels coupled by an intermediate gear wheel this being driven by a pinion of the electric traction motor (fig. 25). On these vehicles, on the one hour rating, powers reaching 1360 H.P. in the case of alternating current (7) and 925 H.P. in that of continuous current (1). The total adhesion locomotives considered in this report have without exception one motor per axle with a maximum one hour rating of 1 000 H.P. with alternat-

[16] *Bulletin of the International Railway Congress Association* for October 1947, p. 896 (HUG).

ing current (15) and 700 H.P. with continuous current (18). In the case of other locomotives (2, 4, 8, 10, 11, 13) each motor axle is driven by two motors either twin or with separate casings. This solution is used either for constructional reasons or because it is not possible to get the power needed from one motor of reasonable size. This is why the most powerful locomotives (8, 10, 11 alternating current, and 2, 4 & 13 direct current) have two motors per axle. An intermediate solution already quoted (3) is that where three motors drive two axles. In the case of direct current motors, the increased number of motors is frequently provided to improve the coupling and to increase the number of economical running notches.

The driving couple or torque of the motors is always transmitted to the axles by one or several trains of gears. The ratio of demultiplication varies from 1 : 1.90 (7) to 1 : 3.57 (13). The wish to lighten weight has led to the use of motors revolving at high speed and this means the gear ratio tends to become higher in spite of the higher maximum speeds. The locomotives equipped with the SLM axle drive known as the Universal (10, 11, 13) have a double reduction gear which in conjunction with the two motors means there are 6 to 8 gear wheels per motor axle (See fig. 26). An arrangement of this kind is due less to the need for a high gear ratio than to the location of the motors relatively to the axles, when in position and to the need to be within the prescribed minimum distance between the gear case and the rail level. Similar diffi-



SLM-Winterthur.

Fig. 26. — The axle drive known as the « Universal » of the Fabrique Suisse de Locomotives at Winterthur (SLM) (10, 11, 13).

culties have led in other locomotives (14, 20) to the use of an intermediate gear wheel between the motor pinion and the gear on the quill (fig. 27).

In many cases, the motor torque is transmitted by a single gear. If the locomotives have one motor per axle, with a high couple, a train of gears on each side of the motor has been thought desirable (1, 5, 6, 7, 9, 12, 21). It is

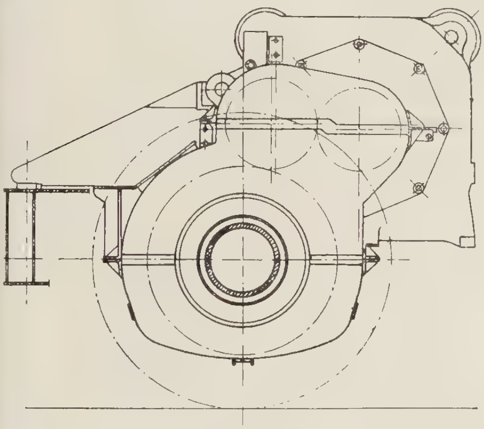


Fig. 27. — Diagram of the transmission of the motion of the motor to the quill on the FS E 424 and E 636 (14, 20).

none the less remarkable to find on certain vehicles power up to 1 000 H.P. per axle at the one hour rate (15) and starting efforts up to 7 500 kgr. (16 300 lbs.) (18) measured on the pitch circle of the gear wheels being transmitted by single gears. This layout is essential for vehicles with motor bogies on which there is insufficient space to provide a train of gears on both sides of the motor.

Gears so loaded should be very carefully finished and be made from material of very high quality. The gears are very frequently made of case hardened and heat treated chrome nickel steel to give 95 to 140 kgr./mm² (60.31 to 88.89 Engl. tons per sq. inch.) (2 to 9, 13 to 16 and 18 to 20) and but rarely in carbon steel of 75 to 85 kgr./mm² (47.62 to 53.97 Engl. tons per sq. inch.) (1, 10, 11). As a rule they are in one piece, the teeth being cut out of the solid, the diameter being too small for fitting a separate toothed ring. The rims of the large wheels always in one piece, are often made of alloy steel, heat treated or not, of 70 to 120 kgr./mm² (44.40 to 76.19 Engl. tons per sq. inch.) or gear wheels of chrome nickel steel (5 to 7, 9, 19), chrome molybdenum (8, 18) or chrome nickel molybdenum steel (3. 4, 14, 20). In other instances, care is taken to avoid the pinion being of the same material as that of the large toothed wheel. This latter or at least its rim is then made of a special cast steel (1, 10, 11, 13, 15) or case hardened and tempered cast steel (16, 21). If need be, the teeth of the large tooth wheel are milled from the solid (16) to avoid the toothed rim breaking and the difficulties which can occur when fitting the rim on the body of the wheel.

In general, the teeth of heavily loaded gears should be case hardened quenched and tempered (4 to 9, 13 to 16, 18, 20). In accordance with the latest experience all the toothed wheels should be treated in the same way even the large ones (14, 16, 20). The result is less wear, greater silence when running and reduced cost of maintenance which balance the extra first cost. The widths of the gear wheels vary from 70 (21) to 170 mm. ($2\,^3/_4''$ to $6\,^{11}/_{16}''$) (15). The greater widths can only be used if the meshing of the teeth of the wheels is perfect. The module of the teeth varies from 9 (10, 11, 13) to 15 (2). The teeth are straight (1 to 4, 10, 11, 14, 15, 17, 20, 21) or slightly oblique by 7 to 9° (5 to 9, 12, 13, 16, 18, 19) by means of which the meshing is more constant and regular, a greater contact and therefore higher permissible loadings as well as greater quietness when running. If the

gears are on one side only the motor bearings are designed to take the axle thrust due to the oblique teeth (8, 13, 16, 19).

The teeth are lubricated by dipping into the oil in the gear case. The highest speeds measured in the pitch circle of the gears may reach 39 m. (128′) a sec. at maximum locomotive speed (13).

Drives.

The drives fitted to the locomotives dealt with in this report are noteworthy for their great variety. As table III shows, on the 21 locomotives considered there are no less than 10 different drives.

Some are only used in their country of origin but others are employed in several countries. Some of these drives have been used for thirty years and more (1, 17, 19), whereas others are quite recent and have been used for the first time on the locomotives in question (15, 18). When looked at broadly, the fact is that none of the existing drives have been given any particular preference, which goes to prove that the object sought can be reached in various ways. The different drives, however, have marked differences as regards space occupied, weight, wear and upkeep. As it is, the whole problem of the drive is still being developed rapidly and continuously so that new designs are often displaced by others in a short period of time. There is no sign, moreover, that this development is likely to end soon. We feel we need not describe in detail each of the many drives of the locomotives considered, as there is a very complete documentation on the subject in the *Bulletin of the International Railway Congress Association* of 1947-1948 [17]. In order to avoid repetition, these publications will be referred to during our report.

Nose suspension of the motor.

The best known and almost universally applied individual drive of axles is that using a nose suspended or tramway type motor. In this system, the motor is carried by a frame stretcher through rubber springs or pads and also directly by the driven axle through two split axle bearings. The gear pinion is mounted on the end of the motor shaft and the gear wheel is keyed to the axle. This method of suspension is, therefore, characterised by the fact that the axis of the motor is parallel with that of the driven axle. Unfortunately, it has the serious defect that only a part of the weight, some 50 % of the motor, can be spring borne. The shocks due to irregularities of the track are transmitted directly from the axle to the motor and to the gears. As they are about proportional to the unsprung weight, these shocks are particularly great in this system of suspension and exercise a harmful effect on the track, the motors and the driving and running gear. The violence thereof also increases with the speed. This type of drive, although highly appreciated for low and mean speed vehicles, is not suitable for high speed locomotives. It is noted that not one of the locomotives in service considered in this report has nose suspended motors : only two series of locomotives under construction (17, 19) will be so fitted. In one (17) the unsuspended weight will be as great as 3 500 kgr. (7 710 lbs) a weight additional to that of the gear wheels (and axle boxes of 2 200 kgr. [4 850 lbs]). One only of the three locomotives will be fitted with gear wheels with elastic rim of the Protex-Maag type [18].

[17] Ad.-M. HUG : Individual axle drive. See *Bulletin* 1947, No. 9, 10 and 12; 1948, No. 2, 4, 7 10 and 11.

[18] *Congress Bulletin*, September 1947, pp. 828 to 830.

TABLE III.

METHODS OF DRIVING THE AXLES.

Series number from table I	Type and number of locomotives in service or under construction		Country	Type of drive.
17 19	Bo'Bo' Bo'Co'	3 2	Belgium Hungary	Nose suspension.
15 18	Bo'Bo' Bo'Bo'	4 3	Switzerland Belgium	Cardan shaft and discs (Brown Boveri).
1	2'Do 2'	107	France	Links and joints (Buchli).
3 21	2'BB 2' Co'Co'	6 2	France France	Quill links carried on silentblocks, free ring (Als-Thom).
2	2'Do 2'	18	France	Quill cup drive.
5 6 7 8 9 12	1'Co 1' 1'Do 1' 1'Do 1' 1'Do 1' 1'Do 1' 1'Do 1'	23 (1) 61 (1) 2 (1) 2 (1) 7 22	Germany Germany Germany Germany Austria Sweden	—do— AEG Kleinow system.
12	1'Do 1'	2	Sweden	Rubber cup drive.
16	Bo'Bo'	50	Switzerland	Section of quill with springs built into the toothed wheel (Brown Boveri).
4	2'Bo Bo 2'	237	Italy	Quill, nest of laminated springs Bianchi and Negri system.
14 20	Bo'Bo' Bo'Bo'Bo'	153 117	Italy Italy	—do— Negri System.
10 11	1'Do 1' (1Ao)Bo(Ao1)	6 6	Switzerland Switzerland	Section of quill, central drive through Oldham coupling, double reduction gear (SLM I Universal drive).
13	(1Ao)Bo(Ao1)	10	Netherlands	Section of quill, central drive through springs, double reduction gear. (SLM II Universal drive).

(1) Estimated.

The tests show that such elastic elements reduce the harmful effects on the gears, prevent tooth breakage, and reduce maintenance costs. In the case of the other series of locomotives (19) the damaging repercussion on the mechanism and on the track will be less serious, as the unsprung weight of the motor will be only 1 000 kgr. (2 204 lbs.) and, in addition, the toothed wheels will be elastic.

The simplicity of this method of motor suspension which has neither quill nor springs, nor articulated joints between the gear wheels, and the axle is so attractive that it cannot be abandoned easily; any new drive, which whilst preserving the simplicity of the nose suspension or tramway type, avoids its undoubted drawbacks, will be of the greatest interest.

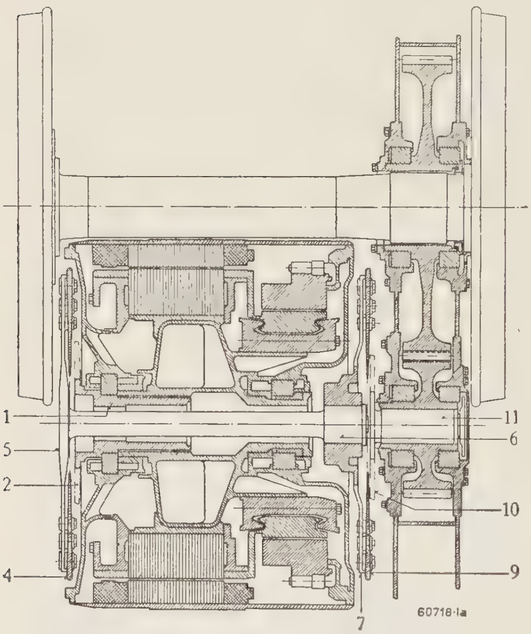


Fig. 28. — Diagram of the Brown Boveri disc drive.

1 = armature sleeve.
2 = driving arm of the sleeve.
4, 9 = flexible disc.
5, 7 = arms of the shaft.
6 = shaft.
10 = arm of the axis of the pinion.
11 = pinion.

Transmission by cardan shaft.

Of the most recent drives examined, those with cardan shafts are not unlike the tramway type drive and, for this reason, best meet the above mentioned condition of simplicity. In this type, the part nose supported is reduced to the gear case. The pinion is fitted between two bearings, whilst the gear wheel is keyed to the motor axle. The motor is rigidly fastened to the frame and so is entirely spring borne. Up to the present the best known of this type of drive is the Brown Boveri disc drive applied to two of the classes of locomotives considered (15, 18) [19] (fig. 28).

A detailed illustrated description of this drive was given in the *Congress Bulletin* of November 1948, pages 685 to 688. Except for the gears and gear case bearings which are lubricated by oil by dipping in the gear case, the main parts of this drive require no lubrication, which helps in the maintenance. Furthermore, with this drive the motor can be made much lighter, as it is less exposed to shocks from the track and the bearings and shaft need not be dimensioned to withstand the reaction due to the thrust on the teeth of the gears. The total weight of motor and drive is frequently less than in the case of a nose suspended motor. This contribution to lightening the motor equipment is much appreciated on occasion.

Drive with motors and gear entirely spring supported.

In the systems mentioned below, the large toothed wheel is not, as usual, fastened on to the axle shaft but is

[19] *Revue Brown Boveri,* 1945, pp. 332 and 333.

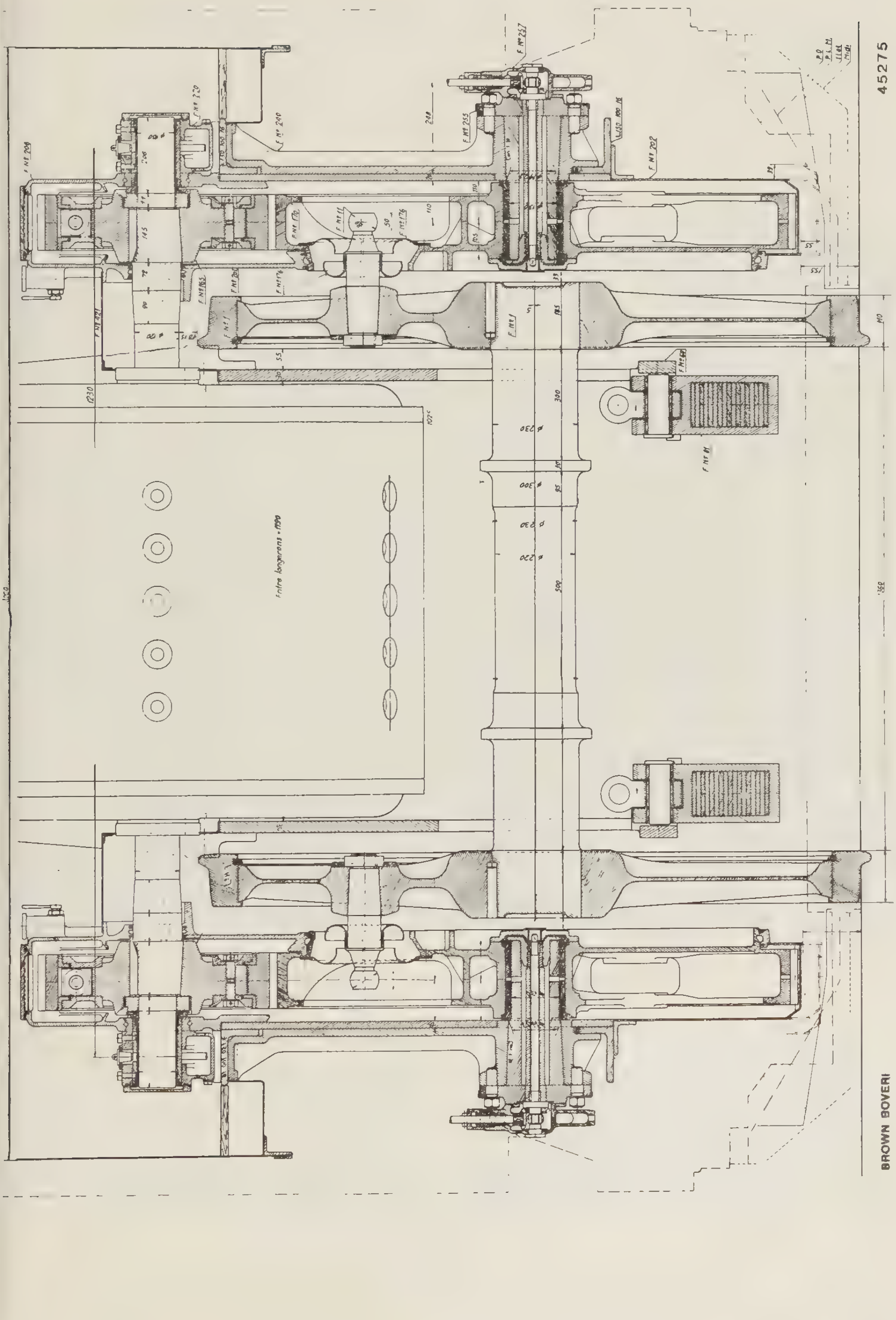


Fig. 29. — Buchli system bilateral drive of the SNCF $2'D_02'$ locomotives (1).

carried on an intermediate shaft. The mechanical connection between the toothed wheel and the axle is obtained in the following way :

a) at one side between the toothed wheel and a wheel of the driven axle (16),

b) at both sides between the toothed wheels and the wheels (1),

c) on the centre line of the locomotive between the toothed wheel and the axle shaft (10, 11, 13),

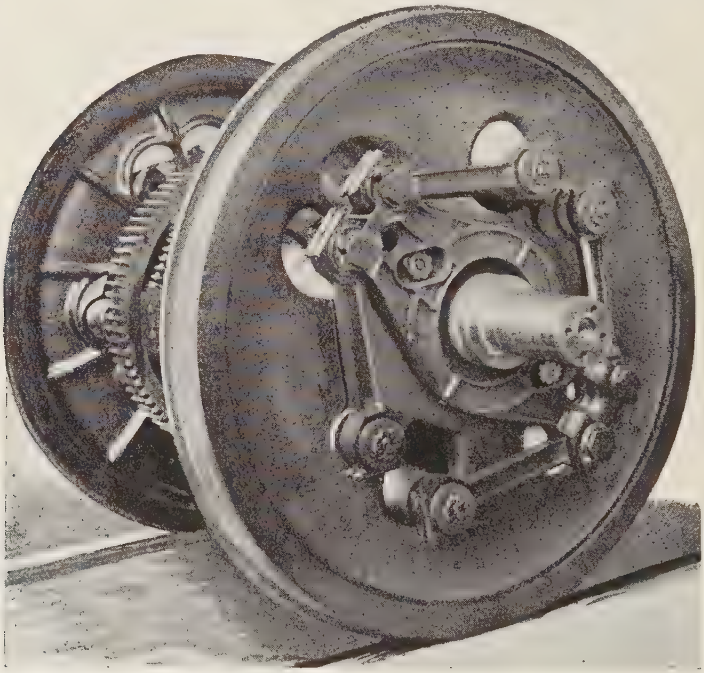


Fig. 30. — Als-Thom system bilateral drive of the SNCF 2′BB2′ locomotive (3).

d) on both sides between the quill carrying the toothed wheel and the wheels (2 to 9, 12, 14, 20, 21).

In this last case, the intermediate shaft is a hollow shaft encircling the driven axle its whole length, and revolving in bearings forming part of the motor casing or of the frame. In cases *a*) and *b*) this intermediate shaft is just a fixed section on which the toothed wheel revolves and in case *c*) a section of quill revolving in two bearings. The various systems of control so distinguished can be classified into 3 groups according to the type of construction of the details of the coupling. In the first group, these elements consist of links and articulation. The «Buchli» drive used on many locomotives is based on this principle (fig. 29). In this system, the toothed wheel is carried off the end of a candlestick bracket fastened to the frame. It was introduced in 1918 and has been described in many publications [20].

[20] *Brown Boveri Bulletin*, May 1922, p. 93. — *Congress Bulletin*, 1930, p. 998 (HUG).

It has given complete satisfaction and is being used always on the new $2'D_02'$ locomotives of the S.N.C.F. (1).

It has not been used in the instances in recent years and there are other systems which are better as regards space, weight, wear and upkeep.

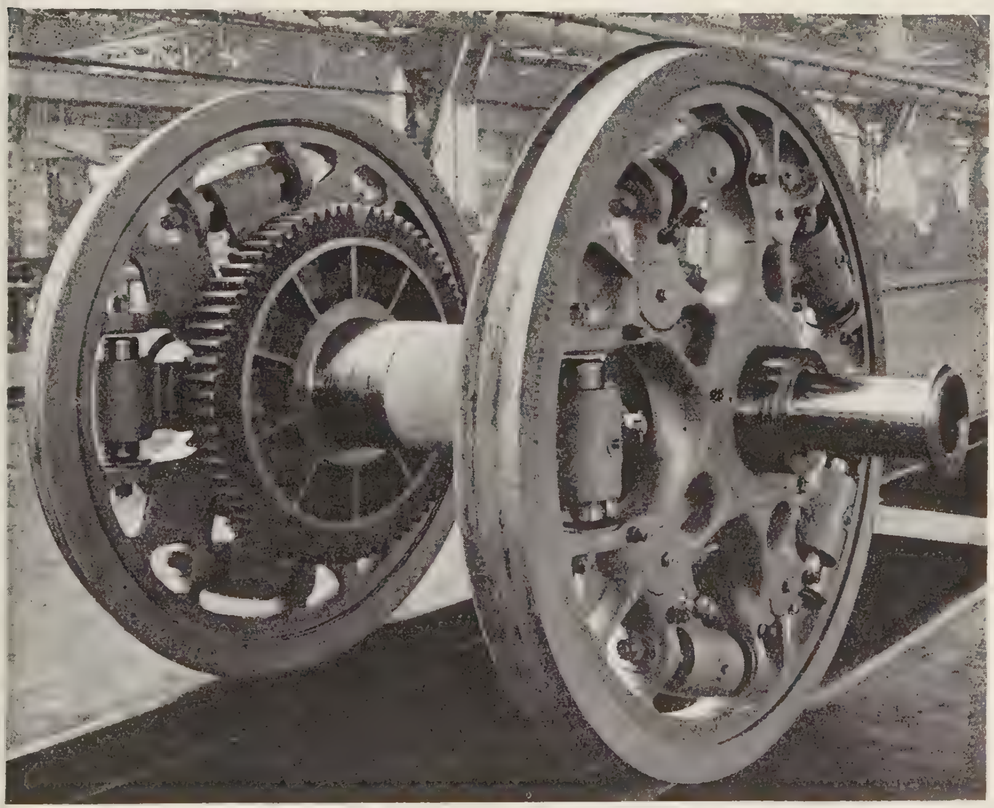


Fig. 31. — Quill cup drive (Mechanism with cups & springs) of the SNCF $2'D_02'$ locomotive (2).

Another application of the same principle is the Als-Thom used on another series of $2'D_02'$ (3) and on the $C_0'C_0'$ locomotives of the SNCF (21) still under construction. This arrangement described in the October 1947, *Bulletin of the International Railway Congress Association*, page 894, consists of a quill, a floating ring and 4 links carried on silentblocks (fig. 30). The use of rubber in the articulation obviates the need for lubrication and reduces wear and upkeep. The weight, however, of this arrangement is still relatively high.

In the second group of drives, the toothed wheel is coupled to the axle through coiled or laminated springs or rubber pads. The most important system in this group, as shown by its applications on many types of locomotives in many countries, is that with

spring cups (2, 5 to 9, 12). Derived from the old Westinghouse geared quill drive, this new arrangement has been developed in America as the quill cup drive. It was widely used in Germany under the name AEG-KLEINOW, where it supplanted all other systems ([21]). The arrangement consists of a quill carrying at each end a number of cups which bear through a spring and its washers on small hardened brackets fastened to the faces of the spoke of the driving wheels (fig. 31). The only drawback of this arrangement is the need to lubricate the rubbing surface of the washers and bearing brackets which are outside the wheels and very exposed to damp and dust. For this reason, the

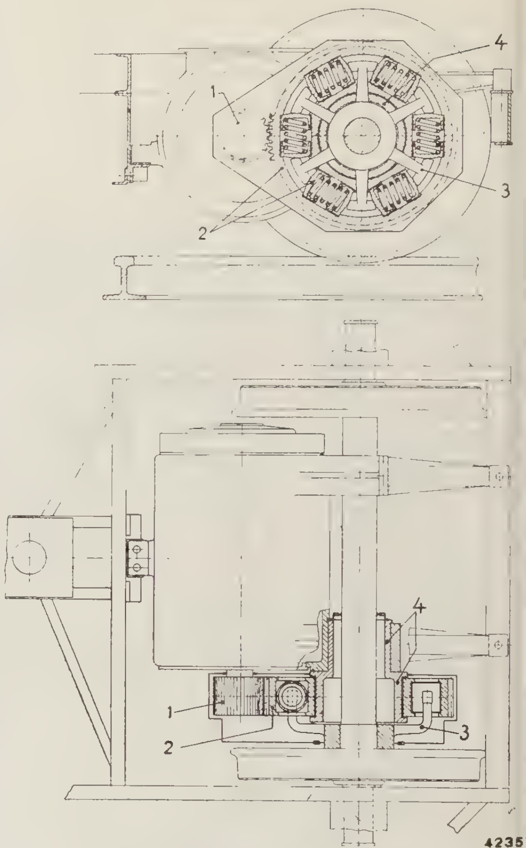


Fig. 33. — Diagram of the Brown Boveri spring drive applied to the CFF $B_0'B_0'$ locomotives (16).

1 = pinion.
2 = toothed wheel with springs inside.
3 = driving spider.
4 = section of quill with toothed wheel bearing.

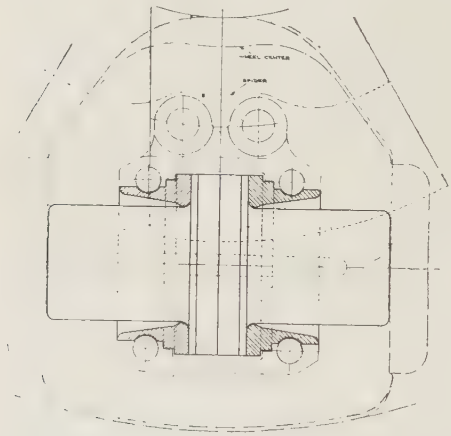


Fig. 32. — Rubber pad of the rubber cup drive of an American locomotive.

Swedish State Railways (SJ) require all these many surfaces to be oiled before each trip. Endeavours were made to replace the cup springs by rubbers (fig. 32). The first tests made on the Pennsylvania Railroad locomotives gave good results. They led to practically the whole of these drives being altered. Further trials are in hand in Sweden (12).

Another interesting solution, which obviates the difficulty of oiling the rubbing surfaces, is the Brown Boveri spring drive. In this gear the cups are set with the body of the toothed wheel. The bearing surfaces are consequently inside the gear case and are automatically lubricated by the gear oil (fig. 33). This drive described in the

([21]) Ad.M. HUG : La commande individuelle des essieux, p. 46.

July, 1948, *Bulletin of the International Railway Congress Association*, p. 415, is especially suitable for small diameter wheels. It has been widely used on electric and diesel electric railcars as well as one series of locomotives examined in this report (16). The toothed wheel has two self aligning roller bearings and revolves round a section of quill bolted to the motor casing. With this arrangement the axle can be examined more easily as it is accessible for its full length.

The idea of using nests of laminated springs to couple the motor shaft to the drive axle was advised for the first time in 1901 on the famous ultra high speed German railcar tested between Marienfelde and Zossen. It was adopted in Italy and fitted to over 2 000 locomotive axles in service and under construction, fitted with a drive based on this principle. The original BIANCHI design [22] (4) has undergone many improvements. The finally adopted pattern is known as the Negri drive (4, 14, 20) and was described in the October 1948, *Congress Bulletin*, page 627, and is shown in fig. 34 & 35.

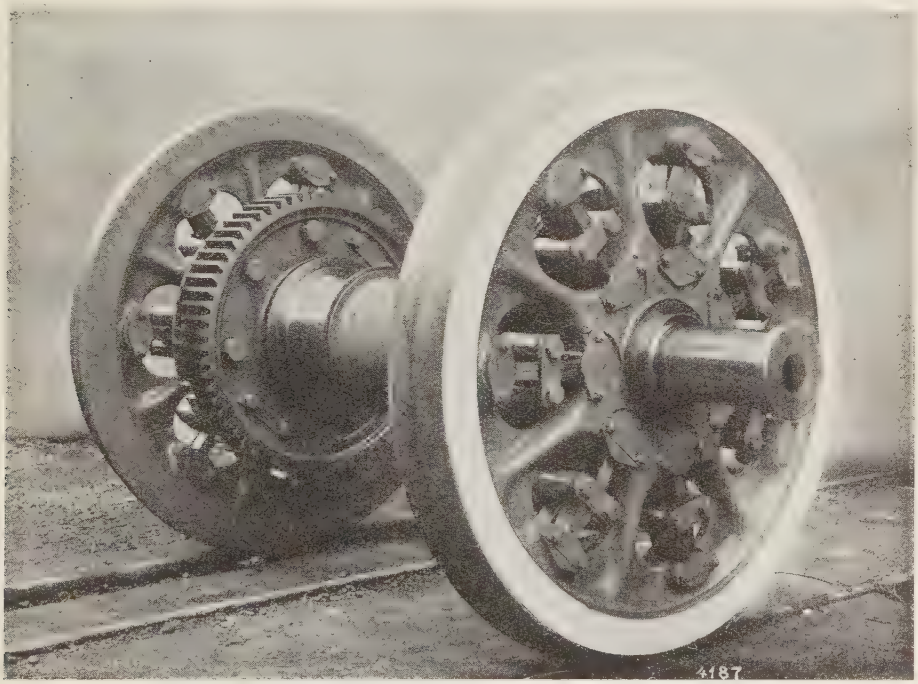


Fig. 34. — Motor axle with quill and drive of the Negri system on the FS (14, 20) locomotives E 424 and 636.

The third group of drives includes those using a mechanism in the form of a parallelogram with slides. The drive known as the « Universal » of the « Fabrique Suisse de Locomotives » at Winterthour (SLM), fixed on two of the

[22] *Rivista tecnica delle Ferrovie Italiane*, 1935, vol. 47, p. 264.

series considered (10, 11) is based on this principle (the Oldham joint). As it has been described in many publications [23], we will limit ourselves to the reproduction of two photographs (fig. 26 & 36). All the details of this drive are fitted in a case fabricated by welding, which also acts as the gear case. It is bolted to the main frame of the locomotive which it strengthens by acting as a stretcher.

In the latest design of the SLM Universal drive (13), the parallelogram mechanism is replaced by 5 elastic elements mounted tangentially inside the large toothed wheel. These elements consist of coiled springs enclosed in sliding cases bearing on the arms of a driving spider (fig. 37).

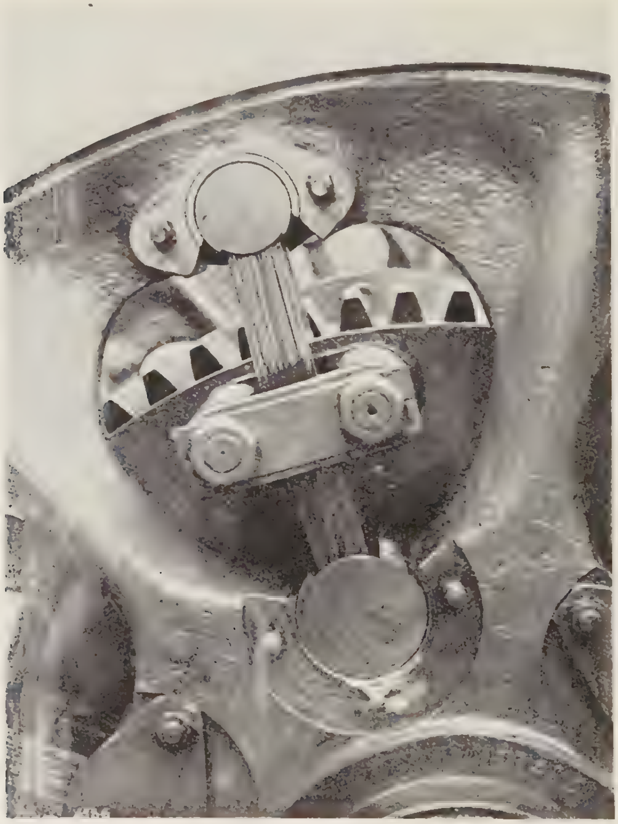


Fig. 35. — Details of the Negri drive shown in fig. 34.

This new type described on page 672 of the November 1948, *Congress Bulletin*, belongs to the second group of spring drives. It has, as regards the coupling of the toothed wheel and the axle, a similitude with the drive through springs in the toothed wheel (fig. 33). Apart from

([23]) Ad.-M. HUG. Individual axle drive, p. 64.

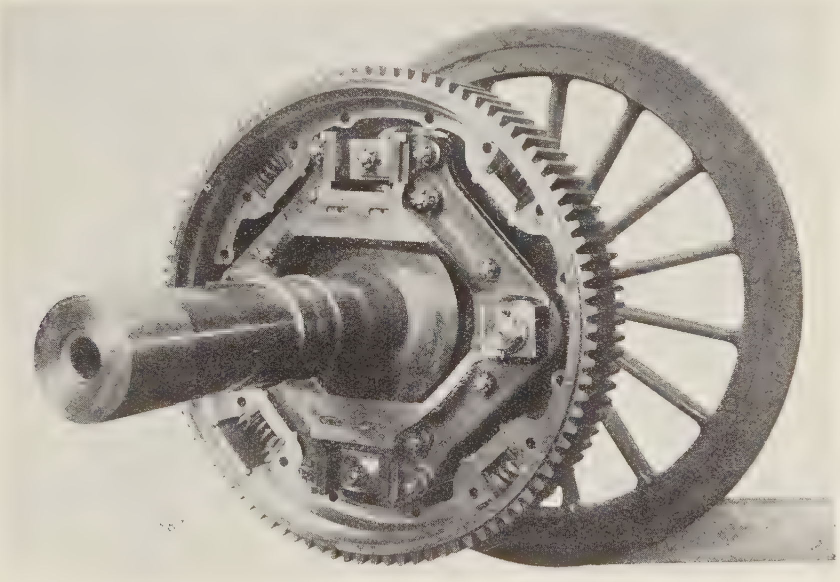
this detail, the characteristic features of the SLM Universal drive are preserved in this variant and, in particular, the double reduction gear and the location of the spider at the middle of the driven axle (fig. 36).

CHAPTER V.

Brakes.

The braking problem becomes more important with increased running speeds The difficulties in the way of solving it also increase in the same proportion. The braking of a railway vehicle is obtained by the action of a couple opposing the rotation of the wheels. Generally, this couple is obtained by the pressure of brake blocks on the tyres. In some rare instances, brake blocks or brake bands acting on special drums are also used as disc brakes.

With electric brakes, the retarding couple is given by the motors : it acts on the braked pairs of wheels through the driving gear. The braking force given by these brakes whether acting separately or together are limited by the adhesion of the vehicles. If the limit be exceeded, the wheels become locked and the braking force becomes very small, the coefficient of friction or slipping of the wheel on the rail being much less than when rolling. If the braking power needed cannot be obtained in this way, electro magnetic brakes can be made use of. This brake develops supplementary brake power by the rubbing of the shoes when pressed down on to the rails. Such brakes, however, are not used on the locomotives dealt with in the report. The tests of such brakes in Germany were discontinued because of the room required



SLM-Winterthur.

Fig. 36. — Mechanism of the SLM Universal drive of the CFF $1'D_0 1'$ and $(1A)B_0(A1)$ locomotives (10, 11).

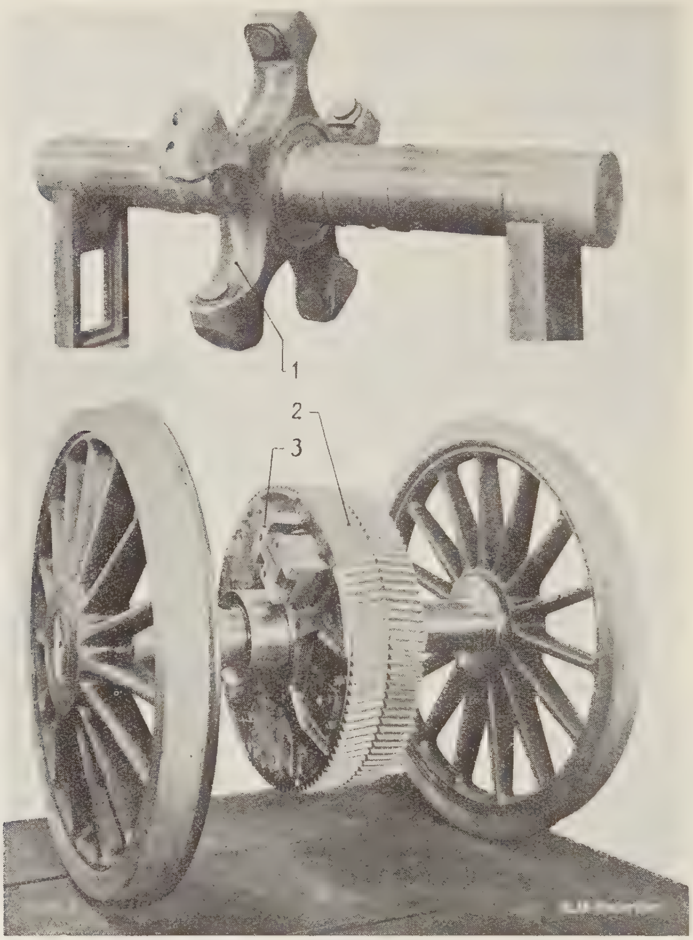


Fig. 37. — Driving axle with spring drive in the toothed wheel with double rim and shaft with 5 armed spider of the SLM II Universal drive of the NS (13) locomotives $(1A_0)B_0(1A_0)$.

1 = spider secured to the centre of the axle.
2 = gear wheel mounted on a section of the quill.
3 = elastic element.

and their high weight, as well as their relatively small efficacy at high speeds. Drum and disc brakes are not used, as it appears they have no real advantages over the brake blocks in use so long. Most of the locomotives we have considered have the usual brake using brake blocks and very few have a supplementary electric brake.

If the skidding of the wheels is to be prevented, the force acting on one axle should not exceed the limiting value of the product of the load on the axle by the coefficient of friction between

the wheel and the rail. According to the investigations carried out by the German Railways [21] this coefficient varies during a brake application between 0.17 and 0.26 for a dry rail and is independent of the running speed (fig. 38). Consequently, to avoid wheel skid with any certainty, whilst getting the maximum out of a brake acting on the wheels, the brake power should from its application, neither exceed nor fall below 15 % of the load on the pair of wheels. Moreover, when the adhesion conditions are bad, skidding of the wheels should be hindered by sanding. The deceleration corresponding to the brake force is about 1.5 m./sec^2, when the rolling resistance and the effect of the rotating masses which tend to lengthen the stopping distance are taken into account. From this it follows that, in the case of the adhesion being fully used, impossible in practice : a train with brake blocks acting on the wheels only can reach, at most, a speed of 200 km. (124 miles) an hour if the length of stop on the level is not to exceed 1 000 m. (1 093 yards).

Seeing that it is not possible to use the adhesion fully for braking, there is, therefore, much greater value in braking every pair of wheels under all the vehicles of an express train. It is, therefore, not surprising to find that all driving axles of the locomotives considered here are braked and that only one series (12) do not brake the carrying axles.

The braking force of brakes using the usual brake blocks is proportional to the pressure on the blocks and to the coefficient of friction between the blocks and the tyre. This depends on many factors, such as the material of the blocks and tyres, the state and temperature of the friction surfaces, the specific pressure of the blocks, the use of single or multiple blocks and shoes, their length and finally on the running speed to a quite particular extent (see fig. 38).

On the locomotives we are considering the brake blocks are made of cast iron exclusively, though of different composition. Other materials, such as synthetic products or asbestos have not been used on locomotives, in spite of their high coefficients of friction and

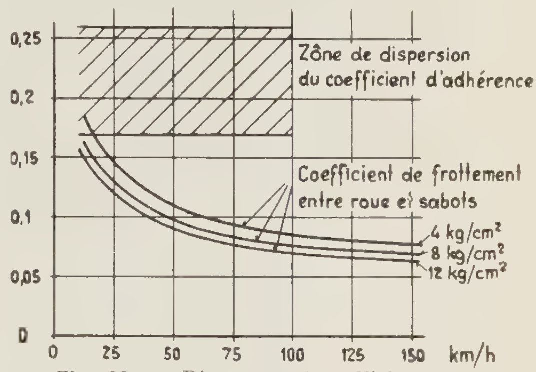


Fig. 38. — Diagrams of coefficients of friction.

Zône de dispersion du coefficient d'adhérence = Zone of the dispersion of coefficient of adhesion. — Coefficient de frottement entre roue et sabots = Coefficient of friction between wheel and blocks.

its independence of speed. This can be attributed, amongst other causes, to the bad conductibility of heat. An effective cooling of the friction surfaces is essential at high speeds : actually because of the great braking power needed, the high temperatures reached by these surfaces can deform the blocks, reduce to a large extent the braking action and result in fissuration or breaking of the tyres and blocks. No special action has been taken on any of the locomotives considered to cool these surfaces as much as possible. In this respect, the streamlining sometimes adopted has an unfavourable effect.

From the many tests carried out, it has been found that the value of the coefficient of friction diminishes with the increase of the specific pressure of the

[21] *Organ für die Fortschritte im Eisenbahnwesen*, 1934, p. 251 (METZKOW).

blocks in the ratio $\frac{1}{\sqrt[6]{p\ (\text{kgr./cm}^2)}}$ between 2 and 12 kgr./cm² ([25]) (28.447 to 170.68 lbs per sq. inch.) To obtain as low a block pressure as possible, and as a result smaller and lighter brakes, the specific pressure of the blocks is kept between 10 and 17 kgr./cm² (142.233 to 241.796 lbs per sq. inch.) as a rule with a maximum of 21.4 kgr./cm² (304.37 lbs per sq. inch.) (7, 8). This implies for the high brake block pressures needed for high speeds the use of the greatest possible number of blocks. The driving wheels, with the exception of one series of locomotives (5), always have blocks on both sides of the wheels. On the other hand, the carrying wheels of certain locomotives (1 to 5, 10, 11) are only braked on one side. Long blocks become deformed under high temperatures, so that the ends do not bear on the tyres. It may then be that the specific pressure on the rubbing surface may exceed substantially that calculated when the total surface of the brake block is taken into account. This explains why the value of the friction apparently increases when the surface of the block is subdivided into two or more parts of the same total surface. A first improvement consequently can be obtained by fixing two shoes in each back (fig. 39). The driving wheels of a large number of high speed locomotives (3, 6 & 9, 12, 14, 19, to 21) are provided with such brake blocks. A further and still greater improvement is to provide an articulated back for each shoe (fig. 40) to let each block adapt itself freely and perfectly to the tyre (10, 11, 15, 16). Fig. 41 (13) illustrates another solution with 4 shoes mounted in pairs in two backs articulated separately.

As early as 1851, Poirée observed the very important fact that the coefficient of friction between block and wheel depended upon the running speed. Today, it is generally known that the value of this coefficient diminishes with the increase of the speed, that is be-

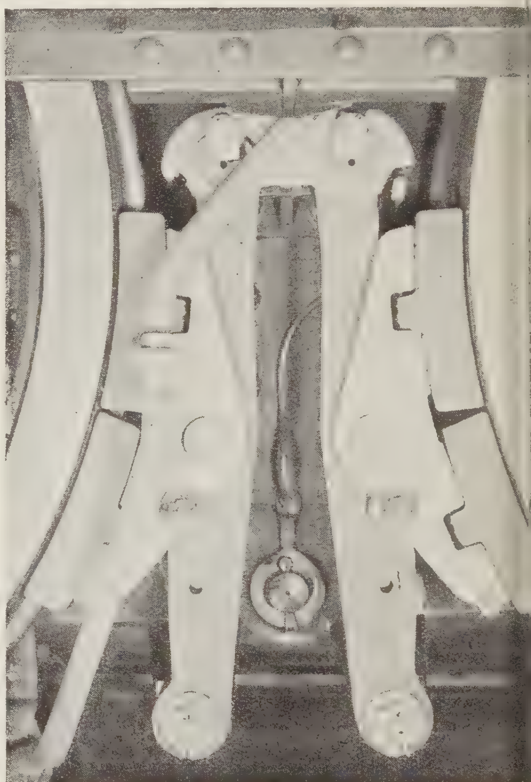


Fig. 39. — Brake block carriers for double blocks.

tween 10 and 150 km. (6 and 93 miles) an hour approx. according to the ratio $\frac{1}{\sqrt[3]{v\ (\text{km./h.})}}$ (fig. 38) ([25]).

Consequently, to get the same brake power at high and low speed, the pressure of the block should increase in the inverse ratio, everything else being equal. This requirement has been met on many high speed locomotives by

([25]) *Electrische Bahnen*, 1941, p. 23 (KOTHER).

providing for high speeds a higher value for the pressure of the brake blocks (6 to 13, 15, 16, 19, 21). The value reaches 150 % (10, 11, 15, 16, 21), 175 % (12), 190 % (6, 9, 13, 19), and even 230 % (7, 8). The values are not raised so high with carrying axles, the following being considered high enough, 60 % in certain cases (10, 11), 120 % (13), 150 % (6, 9) and 190 % (7, 8). It should be noted that, in the case of the German and Austrian locomotives (6 to 9), these high brake block pressures are only applied to the trailing carrying axle, whereas the brake power on the leading carrying axle does not exceed 40 to 60 % in any case. This is done to make certain that the leading pair of wheels will not be skidded and so reduce the danger of derailment. These various arrangements are obtained, for example, by using only one brake

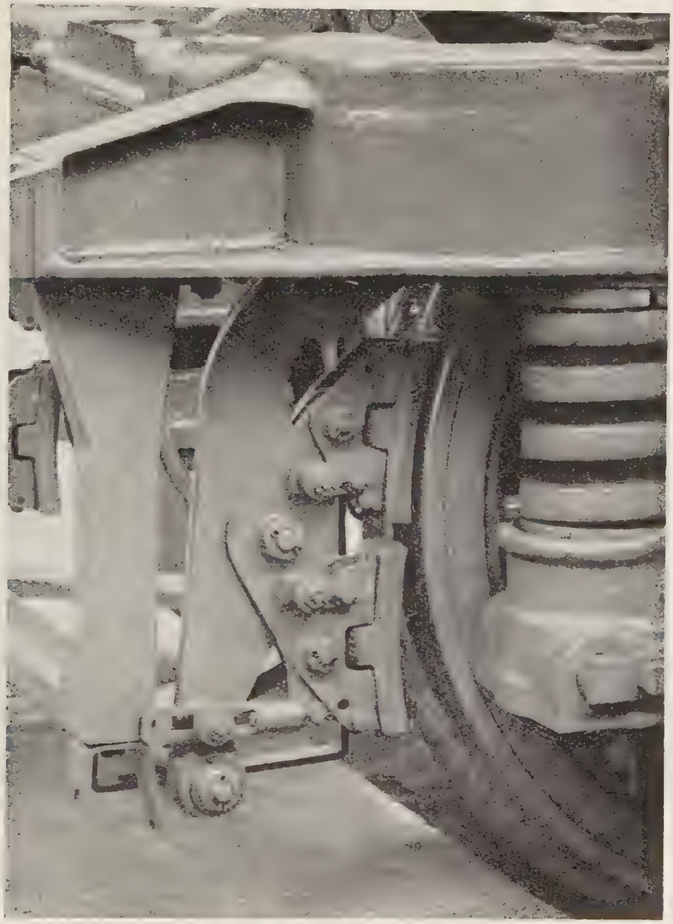


Fig. 40. — Brake block carriers with hinged double back of the Swiss high speed locomotives (10, 11, 15, 16).

cylinder for the lighter braking and two for heavier (6, 9). For light brake application, all that is needed is to cut out one cylinder by means of a valve controlled by a reverser. For this reason, the brake of the leading bogie of one series of $2'B_9B_02'$ locomotives (4) is completely put out of action by the driver closing a valve. With such high pressures the wheels would finish by picking up as the speed is reduced. It is therefore necessary to reduce this pressure when the speed falls. This is done automatically in most cases (6 to 13, 15, 16, 19) whereas in one case only (21) this reduction of pressure is controlled by the drivers.

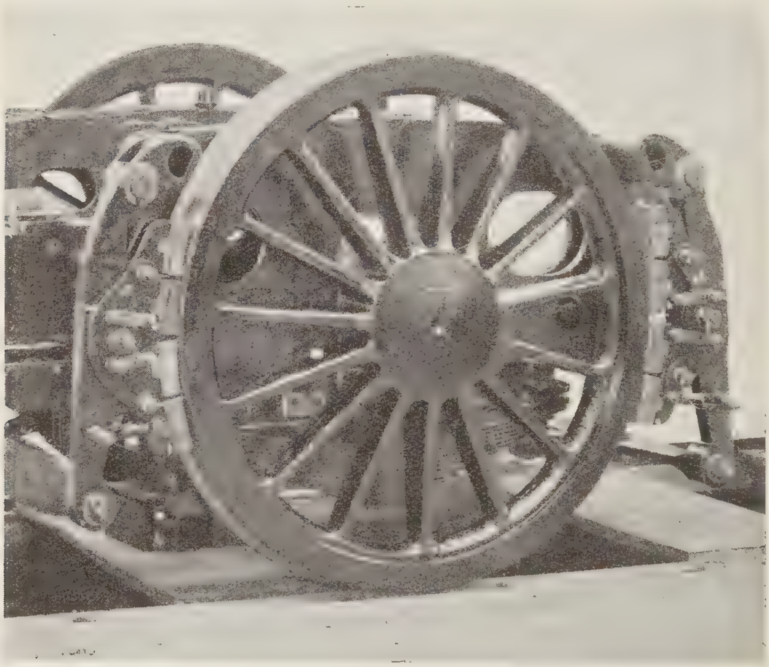


Fig. 41. — Brake block carrier with hinged double backs, each with two backs of the NS $(1A_0)$ B_0 (A_01) locomotive (13).

In order to make full use of the adhesion throughout the whole stopping distance the braking force ought to be maintained at a value as constant as possible near to the value of the adhesion. The brake block pressure ought therefore to have its maximum value corresponding to the speed at the beginning of the braking and diminish progressively when the speed falls in the measure that the value of the coefficient of triction increases. There are equipments which meet this requirement and operate automatically [26]. They are however rather complicated and of recent design. It has not therefore been proved that they are as reliable as is needed in railway working. A set of such equipment is in use at present on only one series of locomotives under consideration (13). This has been

[26] *Organ für die Fortschritte im Eisenbahnwesen*, 1935, p. 37.

made by the Ateliers des Charmilles at Geneva and is known as the « Variastop ». It consists of a triple valve, a regulating valve and a pneumatic relay controlled by an electro-magnet. This latter is fed by such current proportionate to the speed by a dynamo carried on the end of the armature shaft. As soon as a brake application is made, the combined action of these fittings assures the continuous regulation of the pressure acting in the brake cylinders as a function of the speed. In the other cases a two stage regulation given by a relay is considered adequate. The change of pressure is controlled pneumatically by a centrifugal regulator (6 to 9, 12, 19) or electro-pneumatically by a centrifugal interruptor or a contact of a speed indicator (10, 11, 15, 16). This occurs at 50 km. (31 miles/h.) (10, 11, 15, 16), 55 km. (34 miles/h.) (12), 60 km. (37 miles/h.) (6 to 9) or at 80 km./h. (50 miles/h.) (19). At the lower range of pressure the brake block pressure is that used for a long time on medium speed locomotives, i.e. with 70 to 80 % of the weight on the driving axles and 50 to 80 % of the weight on the carrying axles. The reduction in one stop of the brake block pressure to half its initial value or less might lead us to expect a sudden change of the braking action. In practice, the change is barely perceptible because the reduction of the specific pressure of the brake block increases the value of the coefficient of friction and the efficiency of the brake gear. Furthermore, the change from one braking to the other takes place over a prolonged period of time, thanks to the calibrated pipe which slows down the escape of the air from the brake cylinder. Consequently the two stage brake has shown itself adequate and the desire to obtain a progressively varying pressure has lessened.

The above-mentioned graduation of the brake block pressure is obtained by a pressure relay. This relay, in conjunction with a distributor (triple valve) regulates the pressure of the brake cylinders in terms of the pressure of air in the main pipe. A number of such pressure relays of the Knorr (6 tot 12, 19) [27] or Charmilles (13, 15, 16) pattern are in service on the locomotives considered in this report. In addition they allow the brake cylinders to be fed with compressed air directly from the main reservoir. As a result, the pressure in the cylinders can reach 8 kgr./cm² (113 lbs per sq. inch.) if it is 8 1/2 to 10 kgr./cm² (120 to 142 lbs sq. inch.) in the main reservoir (6 to 9) or 6 1/2 kgr./cm² (92 lbs per sq. inch.) if it is 7-8 kgr./cm² (99-113 lbs per sq. inch.) therein (5, 10 to 13, 15, 16). These values are more than twice those of brake systems without pressure relays when the maximum pressure cannot exceed 3.7 kgr./cm² (52.6 lbs per sp. inch.) with the usual main pipe pressure of 5 kgr./cm² (71 lbs per sq. inch.). This increase of pressure makes it possible to reduce the size of the cylinders. In addition to these advantages the pressure relays fill the cylinders more quickly and this helps to reduce the length of the stopping distances.

With a maximum brake power of 230 % for speeds over 60 km./h. and 80 % below it, the theoretical deceleration ought to reach 1.3 m./sec². If we appreciate that the actual deceleration is only about 70 % of the theoretical we must agree that we are still well below the figure of 1.5 m./sec², already quoted which corresponds to the limiting value of the adhesion; this must be attributed mainly to the adhesion not being made full use of at high speed. It is therefore natural to look for a *additional electric brake* acting at high speeds to complete the action of the brake blocks. Two series of locomo-

[27] *Electrische Bahnen*, 1936, p. 134 (Kleinow).

tives (7, 8) are fitted with an electric brake which exerts simultaneously with the brake acting on the brake blocks, a total brake power corresponding to a coefficient of adhesion of about 0.17 for the motor axles between 180 km. and 60 km./h. (112 and 37 m.p.h.). The electric brake consequently should act with its maximum efficacity at at 180 km./h. and its action should be reduced progressively to a minimum efficacity at 60 km./h. In this way it has been possible to get an average effective deceleration of 1.22m./sec^2 during brake tests from 180 km./h. to a stop. This result did not ensure the stopping distance being reduced to the desired extent.

In order to shorten the stopping distance still further, the brake block pressure and the brake power of the electric brake had to be increased still further. But this would bring us more and more into the zone of the dispersion of the coefficient of adhesion of fig. 38 and might risk the skidding of the wheels, even with dry rails and in spite of sanding. Such an increase in brake power is only possible on condition of fitting equipment preventing the slipping of the wheels individually. With this object in view, the German Knorr Company and the American Westinghouse Company have introduced an anti-slip regulator which reduces the brake power on each pair of wheels when it begins to slip and acts only until the normal running is re-established. With this equipment the adhesion can be used to the maximum during the whole of the braking ([28]). No locomotive dealt with in this report is fitted with this device, which may be due to the complication inherent in such fittings, the high cost and to the fact that they need individual brake gear at each pair of wheels. Except for any locomotives with autovariable brakes, as described above, the others, considered in this report, have brake gears which do not differ from the old classic designs. On these vehicles, the maximum brake pressure is 70-77 % (1-3, 5), 80-85 % (4, 14, 20) or 100 % (17,18) of the weight on the motor axles and 50-57 % (1-5) on the carrying axles. Such low brake power naturally means much too long stopping distances from high speeds The high speeds for which the locomotives were built consequently presuppose that the vehicles hauled are fitted with more powerful brakes.

The whole of the locomotives are fitted with the automatic compressed air brake either of one of the Westinghouse types (1-3, 10, 11, 15-18), FS (4, 14, 20), Knorr (5, 19), Hildebrand-Knorr (6-9, 12), Charmilles (17) or Jourdain-Monneret (21); the last three only have variable release. In addition, each locomotive has the direct compressed air brake which, in most cases, is only used for braking the locomotive (shunting brake) by itself. On the Swiss locomotives (10, 11, 15, 16) only this brake is used to regulate the speed of the train as well, like the automatic brake, especially on down grades. All the locomotives have a screw down hand brake in the driver's compartment which generally only acts on two adjacent driving axles. A particular feature found in some locomotives (1, 15) is a brake to prevent the wheels from racing. It is controlled either pneumatically or electro-pneumatically and stops quickly and effectively the rotation of the driving wheels if they race. ([29]).

The number and size of cylinders vary widely. In particular the oldest locomotives have only one cylinder for two axles (1-3, 5, 10, 11, 13, 15-18) or one per axle (4, 19). The present tendency is to provide a brake cylinder

([28]) *Glasers Annalen*, 1941, p. 87 (MOELLER) and *Organ für die Fortschritte des Eisenbahnwesens*, 1942, p. 394 (SCHRÖDER).

([29]) *Revue polytechnique suisse*, 1946, vol. 127, p. 221 (GERBER).

for each wheel braked (6-9, 12, 14, 20, 21). This method, more widely used in Germany and Italy makes it possible to design a light and very simple brakegear which can be taken up easily and the efficiency of which can be as high as 96 %. According to their number, the size of cylinder varies between 8 and 15 inches. They are either cast iron (1-5, 12, 14, 19, 20) or fabricated from steel plate (6-11, 13, 15-18, 21) to save weight. The brakegear is usually of high tensile steel : in some instances it is taken up automatically by S. A. B. (1-3, 17, 18) or Charmilles Stopex (16) automatic slack adjusters. The brake blocks or shoes are at most 380 mm. ($1'2^{15}/_{16}''$) long (17, 18). When longer lengths are needed, the blocks or shoes are divided and carried in a common brake block back or carrier. If there are two sub-divisions (fig. 39, 40) the lengths are 200 to 300 mm. ($7^7/_8''$ to $11^{13}/_{16}''$); if 4 (fig. 41) 150 mm. ($5^{29}/_{32}''$) only.

The compressed air required for braking and control is supplied by motor driven compressors. It would appear that in France and Italy each locomotive (1-4, 14, 20, 21) has two compressors as a matter of principle. Whilst this practice has been followed in Holland and Belgium (13, 17, 18), one compressor per locomotive is considered ample in Austria, Germany, Sweden, Switzerland and Hungary. The total volume of free air for all compressors of a single locomotive varies between 1 500 (5-8) and 4 000 litres per minute (21). Usually it is between 200 and 2 500 litres a minute. Piston compressors are in the majority (1-8, 12-14 and 18-21); rotary compressors are fitted on some locomotives (9-11, 15). Each locomotive has one or several main reservoirs of a total capacity of 700 (13) to 1 500 litres (1-3) (154 to 330 gallons), on the average 800 litres (176 gallons). The pressure is set at 7.5 (107 lbs.) (1-4, 14, 20, 21), 8 (113 lbs.) (5, 10, 15-18), 9 (128 lbs.) (19) or 10 kgr./cm² (142 lbs. per sq. inch.) (6-9, 12, 13).

Some of these locomotives are fitted with rheostatic braking (7, 8, 15) or regenerative braking (10, 11, 19 and partially 1-3, 14, 16). In the two cases mentioned already (7, 8) this brake is used as an additional retarding brake. In the other cases, it is only used to keep the speed to that allowed down the gradients (1-3, 10, 11, 14-15, 19). The brake is intended to transform the mechanical energy so liberated into recoverable electric energy and, what is not less valuable, to increase the safety of operation downhill, to save the mechanical brakes and to reduce the wear of brake blocks and tyres.

CHAPTER VI.

Traction motors and particular features of the electrical equipment.

Traction motors.

The increase in the running speed of locomotives has no direct influence on the type and construction of traction motors. The same motor can be used by selecting suitable gear ratios whatever the maximum speed of the vehicle. As, however, high speed locomotives require greater power, the raising of the speeds has favoured indirectly the tendency to build more powerful motors, whereas formerly, when changing from rod to individual motor drive, the contrary was rather the case. The form of construction of the motors has been influenced more than anything by the need to reduce weight with high speed locomotives and especially those with total adhesion. It will be noted, therefore, in these brief notes that the characteristics of the motors considered below principally relates to the saving in weight and only indirectly to the increase in speed.

The powers and weights per unit of power are shown in Table IV. This

TABLE IV.

CHARACTERISTICS OF TRACTION MOTORS.

Serial No. of table I	Kind of current	Line voltage	Type of locomotive	Number of motors	Nominal voltage across the terminals of the motors	Power per motor under		Speed in % of maximum speed under		Maximum shuntage %	Number of revolutions of the motor at the maximum speed of the locomotiv.	Peripheral speed of the collector at the maximum speed of the locomotiv.	Weight per horse power, continuous rating
						one hour rating	continuous rating	one hour rating	continuous rating				
		volts			volts	H.P.	H.P.			%		m./sec.	kgr./H.P.
1	=	1 350	2'Do 2'	4	1 350	925	880	46	52	74	1 050	42	8.8
2	=	1 350	2'Do 2'	8	675	574	485	50	54	57	1 515	33	6.3
3	=	1 350	2'BB 2'	6	675	715	640	50	52	66	1 430	46.3	7.7
4	=	3 000	2'BoBo 2'	8	1 500	476	428	50	52	45	1 410	38	9.0
5	~	15 000	1'Co 1'	3	P	990	910	75	79	—	1 300	44.2	5.4
6	~	15 000	1'Do 1'	4	P	1 030	965	83	86	—	1 330	45.5	5.1
7	~	15 000	1'Do 1'	4	P	1 360	1 260	100	100	—	1 165	46.4	4.4
8	~	15 000	1'Do 1'	8	SP	695	590	100	100	—	2 110	47.5	4.8
9	~	15 000	1'Do 1'	4	P	1 220	1 140	75	81	—	1 300	45	4.4
10	~	15 000	1'Do 1'	8	SP	714	673	67	69	—	1 575	41.2	3.8
11	~	15 000	(1Ao)Bo(Ao1)										
12	~	15 000	1'Do 1'	4	P	880	775	70	76	—	1 570	47.7	5.9
13	=	1 500	(1Ao)Bo(Ao1)	8	750	560	475	64	67	50	2 000	48	3.7
14	=	3 000	Bo' Bo'	4	1 500	540	475	51	53	65	1 830	45	9.0
15	~	15 000	Bo' Bo'	4	P	1 000	860	60	65	—	1 180	45	4.9
16	~	15 000	Bo' Bo'	4	P	640	586	66	69	—	1 870	40	3.2
17	=	3 000	Bo' Bo'	4	1 500	675	560	36	41	60	1 720	51	9.8
18	=	3 000	Bo' Bo'	4	1 500	715	605	39	42	71	1 060	41	9.1
19	~ 50	16 000	Bo' Co'	5	P	640	580	80	80	—	2 500	—	2.6
20	=	3 000	Bo'Bo'Bo'	6	1 500	540	475	51	53	65	1 830	45	9.0
21	=	1 350	Co'Co'	6	675	—	550	—	54	70	1 650	42	6.6

shows that the weight per horse power under continuous rating varies between remarkably wide limits, that is between 9.0 and 3.7 kgr./ch. (20 lbs. and 8 lbs. per H.P.) for direct current motors and between 5.9 and 3.2 kgr./ch. (13 lbs. and 7 lbs. per H.P.) for alternating current motors, whereas in the case of reduction motors for 50 period three phase current, which are lighter, it is 2.6 kgr./ch. (5.8 lbs. per H.P.).

The reduction in weight of the new motors (7-11, 13, 15, 16) has been obtained by building and dimensioning all details in such a manner that all materials used are employed in the best way mechanically, electrically and thermally and are subjected to uniform stresses within reasonable limits. This progress has been achieved without modifying or exceeding the stresses as allowed and to some extent included in international prescriptions. In this order of ideas it may be mentioned that the armatures of the lightest motors (13, 16) are not fitted with the usual type of shaft. The body is in the shape of a hollow drum, the ends of which are used to carry the collector, the gear and the bearings. Notable weight savings have been obtained by using motor casings fabricated from steel plate by welding (7-12, 15, 16, 19) in place of steel castings. In other cases some progress has been made by using high tensile new materials especially in the insulation. On some locomotives (11) the windings of the armature have been made of aluminium. Although this saved weight the use of light metal must be regarded as a war time measure forced on us as a temporary measure and the drawbacks were found to outweigh the benefits.

An increase in the power of the motors can also be obtained by using higher peripheral speeds for the collector and armatures. As table IV shows, speeds up to 51 m./sec. (167 ft./sec.) are allowed in the case of the collectors at the maximum speed of the locomotive (17), whilst the peripheral speed of the armature can reach 64 m./sec. (210 ft./sec.) (7, 12) at the same moment. With the same object the ventilation of the motors can be forced still further. All the locomotives considered have forced ventilation motors. The quantity of air needed for each motor can be as much as 3.5 m³/sec. (123.59 cu. ft. per sec.) and 4.1 dm³/sec. (14.47 cu. ft. per sec.) and per horse power continuous rating (18). On certain locomotives (5-9, 12) the cooling is carried still further by using separate fans and air ducts for the armature and for the windings.

Finally, it is remarkable to find that almost all the motors are fitted with roller bearings grease lubricated. There are only three classes of locomotives (1, 10, 11) still fitted with plain bearings and three others (15, 16, 19) with roller bearings running in oil. Motors with grease lubricated roller bearings run 200 000 km. (125 000 miles) without intermediate greasing, a particularly desirable feature in the case of high speed locomotives running long distances between stops and with an intensive daily use.

On the other hand, most of the bearings of the quills forming part of the motors are fitted with plain bearings with oiling rings (2, 3), lubricating pads (4-9, 14, 20) or pump lubrication (21). Here again, however, grease lubricator roller bearings have already been introduced (12).

Current pick up.

Of all the electric equipment the current pick up on the roof of the locomotives is the apparatus most seriously affected by high speeds. On the one hand, it has to work freely under all conditions in spite of the wide range of temperature in the open and stand up against the effects of wind, rain, snow or ice. On the other, it has to

follow instantaneously all variations in height of the catenary wire and not to leave the contact wire even though the time available for their movement diminishes as the speeds increase. To meet all demands, a perfect current collector has to have qualities difficult to realise and somewhat contradictory as the moving part has to be at once very stable to stand the shocks, as light as possible and sensitive to vertical forces. The collector as a whole cannot be given an aerodynamic form though the makers do endeavour to give such a form to each of the constituent parts (fig. 42). Freedom of movement is improved by fitting roller bearings at all joints.

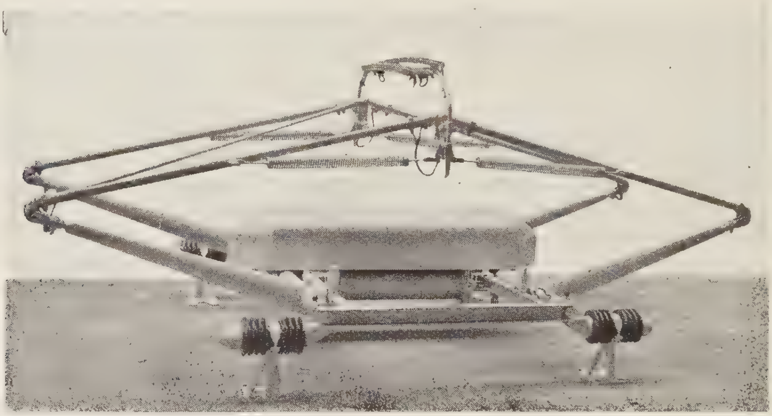


Fig. 42. — Aerodynamic light weight current pick up, Oerlikon type.

When the locomotives are stationary the vertical pressure exerted by the collector is 4-5.5 kgr. (8.8-12.2 lbs.) in the case of alternating current and 7-10 kgr. (15-22 lbs.) with direct. When running the pressure depends on the speed of the locomotive, that of the wind and on its direction, the position of the pantograph on the roof of the vehicle as well as on the shape of the front of the engine and the roof. For these reasons, the vertical pressure can reach 30 kgr. (66 lbs.) with the pantograph when placed at the forward end of the vehicle, at 120 km./h. (74 m./h.) (1) whilst being very low on the trailing pantograph at the same speed. In order to correct to some extent these differences, compensating frames are fitted occasionally on the frames of the pantograph (1, 2), the effect of which is to reduce the unduly high values and increase those which are too low. Such methods in conjunction with the use of current collectors having tubular shoes have made it possible to reduce the vertical pressure to 16 kgr. (35 lbs.) at 160 km./h. (100 m./h.)

In most cases, the current collectors have multiple shoes fitted on levers turning about a horizontal axis at right angles to that of the track. The wearing strips are made of copper, brass or annealed steel in the case of direct current (1-4, 14, 20) and in aluminium for alternating current (9-12, 15, 16, 19). In certain cases, carbon strips are used for both kinds of current (5-8, 13, 17, 18) and in others carbon is only used during tests (1, 16). Carbon strips are often introduced with the object of diminishing radio-phònic disturbances (5-8, 13, 16-18). The S. N. C. F. on the other hand point out that their only

reason for this measure was to reduce the wear of the contact wires (1). Sometimes, copper or steel collectors are used but only temporarily in winter and during frost, carbon or aluminium being used normally the rest of the year.

There are always two collectors per locomotive. One (Italy, Switzerland, Belgium) or two (Austria, Germany, Sweden, Holland, Hungary) are raised simultaneously when running according to the working conditions, the kind of construction and the speed or according to the intensity of current picked up (France). If it is usually only necessary to raise one collector the one generally used is that at the trailing end of the locomotive and the other remains down in reserve in case of damage to the first.

Electrical equipment.

High speed locomotives require a large number of running notches. On direct current locomotives there are 20 (14) to 66 (18) of which 8 (4, 17, 18) to 33 (21) are the economical ones. On the single phase locomotives there are 15 (5, 6, 8) to 40 (12). The Austrian and German locomotives with 15 to 20 running notches at the controller are fitted with a fine regulating device with collector which makes it possible to ensure a transition practically continuous from one notch to the next [30]. This regulator can be built to give between each pair of notches an intermediate notch which is locked in for at most 30 secs. (6, 7, 9).

The different systems of regulation can be classified as follows :

- system with graduators using the principle of notches (insérateurs) for regulating at high voltage the single phase current (10, 11, 12);
- system using graduators with slides also for regulating on the high voltage side of single phase current (15) [31];
- system using contactors grouped in combiners (combinateurs) and controlled by cam-shafts, used with direct current (1, 17, 18) and single phase (5-9);
- system with individual contactors controlled electro-pneumatically or electro-magnetically for direct current (2-4, 13, 14, 20, 21) and alternating (16, 19).

The frequency with which it is necessary to alter the regulation on a locomotive increases very much with the speed. Hand control of the graduators and the combiners (combinateurs) becomes too fatiguing. This is why a system of this kind is only used on one series of locomotives (5) all the others being fitted with electric (6-12, 15, 17, 18) or electro-pneumatic servo-motors (1). Brake applications and accelerations are also more numerous on express trains. When recovering speed, it is important to get the full tractive power quickly so that it is essential that the speed of working of the servo-motors be increased. As compared with the other systems, individual contactors have the merit of responding immediately to the orders of the operator, the reason why this system of regulation has been selected in certain cases (16).

The drivers of express train locomotives have to give constant attention to the observation of the signals and of the track. It is, therefore, necessary to simplify as far as possible the driving of these locomotives. For this reason the driving tables are well arranged without too many appliances to look after nor too many instruments or signals to be consulted. The cabs have large windows fitted with wipers and anti-freezing devices. They are well heated and lighted. The staff on long runs generally sit down. Driving standing now is found only on the CFF (10,

(30) *Bulletin of the International Railway Congress Association*, 1930, p. 930 (Wechmann).

(31) *Brown Boveri Review*, 1945, p. 336.

11, 16) and on some old series of German locomotives (5).

High speeds also require improved safety devices. The « dead man's handle » is found in many locomotives (5-13, 15-18); those locomotives not so fitted always have two men in the cab. Automatic devices are also fitted which stop trains passing an outer signal at danger (7, 8, 10, 11, 15, 16). In some instances, it is considered that all that is needed is to give a warning and to repeat the position of the signal at danger on the locomotives (1-3, 21).

In order to facilitate double heading when one engine is unable to handle heavy high speed trains, many locomotives are fitted with multiple control gear (10, 11, 13, 14, 16-19, 21). It is also used to control train sets with two locomotives in push-pull service, one at each end of the set, or with one locomotive at one end and a driving coach at the other (16).

CHAPTER VII.

The riding of high-speed locomotives in service.

The experiments made with high speed locomotives in service are not yet numerous enough nor conclusive. Only two series of the 21 considered herein actually use in regular working their maximum speed (2, 16). The results of some few test runs do not justify a definitive opinion. Nevertheless, the results obtained in regular working at speeds of 120 and 125 km. (74 and 77 miles) an hour can be stated as being favourable. All the types of construction adopted appear to be suitable and no defect of principle has been noted so far. Some small improvements are needed in certain cases, mainly in the way of strengthening and damping the mechanical part.

The daily distance run by high speed locomotives reaches 1 500 km. (930 miles) and the annual distance covered 240 000 km. (150 000 miles) (12). The distance between general repairs varies between 180 000 km. (1 and 3) and 500 000 km. (112 000 and 310 000 miles) (10, 11, 15, 16). Intermediate repairs for dealing with the tyres take place according to needs between 140 000 km. (87 000 miles) and 250 000 km. (156.000 miles).

As regards cost of repairs per km., it is no higher than for other comparable locomotives running at lower speeds. When comparing the latest with the oldest locomotives we find a great reduction in the consumption of lubricating oil in the former. For example it is only 1.6 to 2 kgr. per 1 000 km. (3.5 to 4.4 lbs. per 630 miles) with the new locomotives against 24 kgr. (53 lbs.) per 1 000 km. for a series built in 1940 (10, 11). The consumption of grease for the roller bearing axle boxes is negligible.

The information given above shows the need for making more tests on a wider scale before an opinion can be expressed on the valuable features or the possible defects of the high speed locomotives. For such tests, it is necessary that these vehicles be able to develop their maximum speed in regular service which largely depends on the speed of reconstruction of the railways and their betterment.

* * *

The work of the Reporters has been made much easier by the help of the Administrations, who have been good enough to reply to the questionnaires sent out and to supply adequate documentation. We wish to thank them warmly. We would also like to express our gratitude to the « Fabrique suisse de Locomotives et de Machines », at Winterthour, the « S. A. Brown Boveri et Cie », at Baden, the « Ateliers des Charmilles, S. A. », at Geneva, and the « Société Internationale des Applications Isothermos », at Paris, for the valuable photographs and data they supplied.

[621 .33]

Actual state of Railway electrification in the world.

We think that the following tables giving the results of an investigation made by the International Railway Congress Association regarding the actual state of railway electrification in the world will be of interest to our readers. This investigation was made at the request of the British Railways.

The replies received up to the present have been summarised in these tables.

Any additional reply, which may reach us in the future, will be published in the Bulletin.

COUNTRIES	UNITED ST. OF AMERICA	FRANCE, ALGERIA, TUNISIA, COLONIES AND FRENCH PROTECTORATES		
RAILWAY ADMINISTRATION	Pennsylvania Railroad Company.	French National Railways.	Algerian Railways.	Morrocan Railways Company.
I *Length of the electrified system.*				
— main tracks	1 821 miles	4 050 miles	102 miles	—
— secondary tracks	430 miles	1 335 miles	24 miles	—
— total mileage	2 251 miles	5 385 miles	126 miles	—
— main lines	—	2 258 miles	102 miles	360 miles
— secondary lines	—	—	24 miles	—
— total mileage	670 miles	—	126 miles	—
II *Feeding current.*				
— nature	Single phase 25 p.p.s.	Direct	Direct	Direct
— tension	11 000 V.	1 500 V. (1)	3 000 V.	3 000 V.
— kind of feeder	Catenary.	Catenary.	Catenary.	Catenary.
III *Year of electrification*.	1915 to 1937	1900 to 1947	1932 to 1939	1926 to 193
IV *Kind of traffic*	Passengers-goods.	Passengers-goods.	Goods- less passengers.	Passengers-goods.
V *Reasons and results of the electrification*	Easiness and economy of operation of lines with heavy traffic.	Improvement of operation, Returns of electrified lines, Saving of coal (2.2 millions of tonnes in 1947), 21 % of the total traffic is electrified, 9 % of the length of the lines is electrified.	Increase of the traffic from the mines on single track line with gradients, Reduction of the running cost.	Low grade feed water f boilers, Difficult approach of fe water, Satisfactory sults.
VI *Electric locomotives.* Total number of the stock . . . . . max. speed	268	784	31	26 — 56 p.m
— passenger . . . max. speed	100 — 100 m.p.h.	126 — 80 m.p.h.	2 — 65 m.p.h.	—
— freight . . . . max. speed	140 — 70 m.p.h.	180 — 65 m.p.h.	29 — 46 m.p.h.	—
— composite. . . max. speed	—	414 — 65 m.p.h.	—	—
— other types. . . max. speed	28 — 25 m.p.h.	64 — 43 m.p.h.	—	—
VII *Electric motor coaches.*				
— total number of the stock.	432	999	None.	10
— motor coaches	385	472		—
— trailers.	47	527		—
— maximum speed	77 m.p.h.	21/100 m. p. h.		56 p.m
VIII *Annual consumption in millions of Kwh. (year)*	1 245 (1947)	902 (1947)	28.1 (1947)	43

(1) Except 133 km. (82 miles) of suburban lines equipped between 1900 and 1936, with 650 V. direct current 3rd rail.—Except 63 km. (39 miles) of line (from Tour-de-Carol to Villefranche) equipped in 1911 with 85 direct current with catenary line. — Except 47 km. (29 miles) of line (from Villefranche to Perpignan) equip in 1913 with single phase current 16 2/3 cycles—12.000 V. with catenary line.

GREAT BRITAIN	HUNGARY	ITALY			NORWAY
London Transport Executive.	Hungarian State Railways.	North Milan Railway.	Electric Tramways of Brescia.	Soc. Vénitienne pour la construction et l'exploitation des Chemins de fer secondaires en Italie.	Norvegian State Railways.
442 miles — 599 miles — — (2) 203 miles	— — — 116 miles — —	— — 153 miles — — —	— — — 89 miles — —	— — — 53 miles — —	— — 640 miles 472 miles — —
Direct 630 V. 3rd rail.	Single-phase 50 p.p.s. 16 000 V. Catenary.	Direct 3 000 V. Catenary.	Direct 1 200 V. Catenary.	Single phase 25 p.p.s. 6 000/600 V. Catenary.	Single phase 16 2/3 p.p.s. 15 000 V. Catenary.
1905	1932	1929 to 1948	1905 to 1931	1909	1922 to 1948
Passengers.	Passengers-goods.	Passengers-goods.	Passengers-goods.	Passengers-goods.	Passengers-goods.
Improvement of operation, Increase of line capacity.	Considerable reduction of expenditures.	Saving in working, Improvement in comfort, Reduction of coal imports.	Improvement of operation, Increase of trains speeds. Increase of traffic.	Saving in working, Excellent results.	Improvement of operation, Reduction of coal imports.
18 — 60 m.p.h. 18 — — — —	32 — 3 — 41 m.p.h. 29 — 62 m.p.h. —	6 — 50 m.p.h. 5 1 — —	7 5 — 31 m.p.h. 2 — —	6 — 28 p.m.h. — — 6 —	62 — — 60 — 68 p.m.h. 2
873 212 661 56 m.p.h.	None.	54 27 27 49 m.p.h.	220 25 195 37 m.p.h.	43 16 27 28 p.m.h.	104 36 68 74 m.p.h.
604.6	60 (1943)	14 (1947)	3.2	2.7 (1947)	84

The figures given refer to tracks belonging to the London Transport Executive.
In fact, the system operated has 497 miles of main tracks, 655 miles as total mileage of tracks and 233 miles of lines.

	COUNTRIES	NETHERLANDS	SWEDEN	
	RAILWAY ADMINISTRATION	Netherlands Railways.	Oxelosund-Flen Vastmanlands Railway.	Swiss Federal Railways.
I *Length of the electrified system.* — main tracks . . . . — secondary tracks . . . . . — total mileage : . . . . . — main lines . . . . — secondary lines . . . . . . — total mileage	 — — 807 miles — — —	 — — 28 miles 28 miles — 28 miles	 — — 3 479 miles — — 1 775 miles
II *Feeding current.* — nature . . . . — tension . . . . — kind of feeder	 Direct 1 500 V. Catenary.	 Single phase 16 2/3 p.p.s. 16 000 V. Catenary.	 Singlephase 16 2/3 p.p. 15 000 V. Catenary.
III *Year of electrification.*	1908 to 1948	1947	1918 to 1946
IV *Kind of traffic*	Passengers.	Passengers-goods.	Passengers-goods.
V *Reasons and results of the electrification*	Saving of coal. Increase of line capacity. Improvement in comfort. Very satisfactory results.	Coal imports cancelled. Use of national production of electrical energy. Reduction of operating costs, Increase of line capacity.	Coal imports cancelled Use of national pro duction of electrica energy. No more smoke i long tunnels. Increase of train speed. Increase of transpor capacity (high gra dients lines). Reduction of 19 % i working and hea ting expenses.
VI *Electric locomotives.* Total number of the stock . . . . . max. speed — passenger . . . max. speed — freight . . . . max. speed — composite. . . max. speed — other types. . . max. speed	 3 — 100 m.p.h. — — — 3	 none (locomotives are hired from the Swedish State Railways) — — 56 m. p. h.	 595 435 — 77 m.p.h. 42 — 98 — 28 m.p.h.
VII *Electric motor coaches.* — total number of the stock. — motor coaches . . . . . . — trailers. . . . . — maximum speed	 436 (3) — — 87 m.p.h.	 None.	 73 73 — 46 to 93 m.p.h.
VIII *Annual consumption in millions of Kwh. (year)*	160 (1939) 98.3 (1947)	2.9	806

(3) The stock of motor coaches is as follows:
94 motor coaches with 94 trailers
27 double sets
16 triple sets
19 quadruple sets
14 quintuple sets.

SWITZERLAND

Bernese Alpes Railway, Berne-Loetschberg Simplon.	Rhaetian Railway.	Viège-Zermat Railway.	Yverdon-Sainte-Croix Railway.	Fribourg Railway.	Emmental-Burgdorf-Thun Railway.
— 142 miles 100 miles 43 miles 142 miles	Length not indicated. Approximately 217 miles of lines.	— — — — — 27 miles	15 miles — 15 miles 15 miles — 15 miles	— — 67 miles 60 miles 6.2 miles —	— — — — — 105 miles
Single phase 16 2/3 p.p.s. 15 000 V. Catenary.	Single phase 16 2/3 p.p.s. 11 000 V. Catenary.	Single phase 16 2/3 p.p.s. 11 500 V. Catenary.	Single phase 16 2/3 p.p.s. 15 000 V. Catenary.	Single phase 16 2/3 p.p.s. 15 000 V (4) Catenary.	Single phase 16 2/3 p.p.s. 15 000 V. Catenary.
1910 to 1928	1907 to 1922	1930	1945	1901 to 1947	1932 to 1946
Passengers-goods	Passengers-goods.	Passengers-goods.	Passengers-goods.	Passengers-goods.	Passengers-goods.
Not mentioned.	Reduction of coal imports. Use of national production of electrical energy. Traffic improvements. Increase of train speed and of number of trains.	Increase of train speed and train load, Increase of traffic.	Need of increasing the number of trains in spite of the shortage of coal, Electrification has increased the passenger traffic by 430 % and goods traffic by 20 %.	Reduction in expenditure.	Saving and modernisation of rolling stock, Increase of train speed and of number of trains. Reduction of coal imports, No more smoke.
41 — — 39 — 77 m.p.h. 2	41 — — 36 — 40 m.p.h. 5	6 — 31 m.p.h. — — — —	None.	None.	19 — — 12 — 50 m.p.h. 7
25 — — 69 m.p.h.	34 34 — 40 m.p.h.	None.	5 5 — 40 m.p.h.	59 21 38 46 p.m.h.	19 19 — 46 to 56 m.p.h.
30	26.1	1.7 (1947)	0.5	3.8	13.8 (1946)

) — and direct current 960 V.